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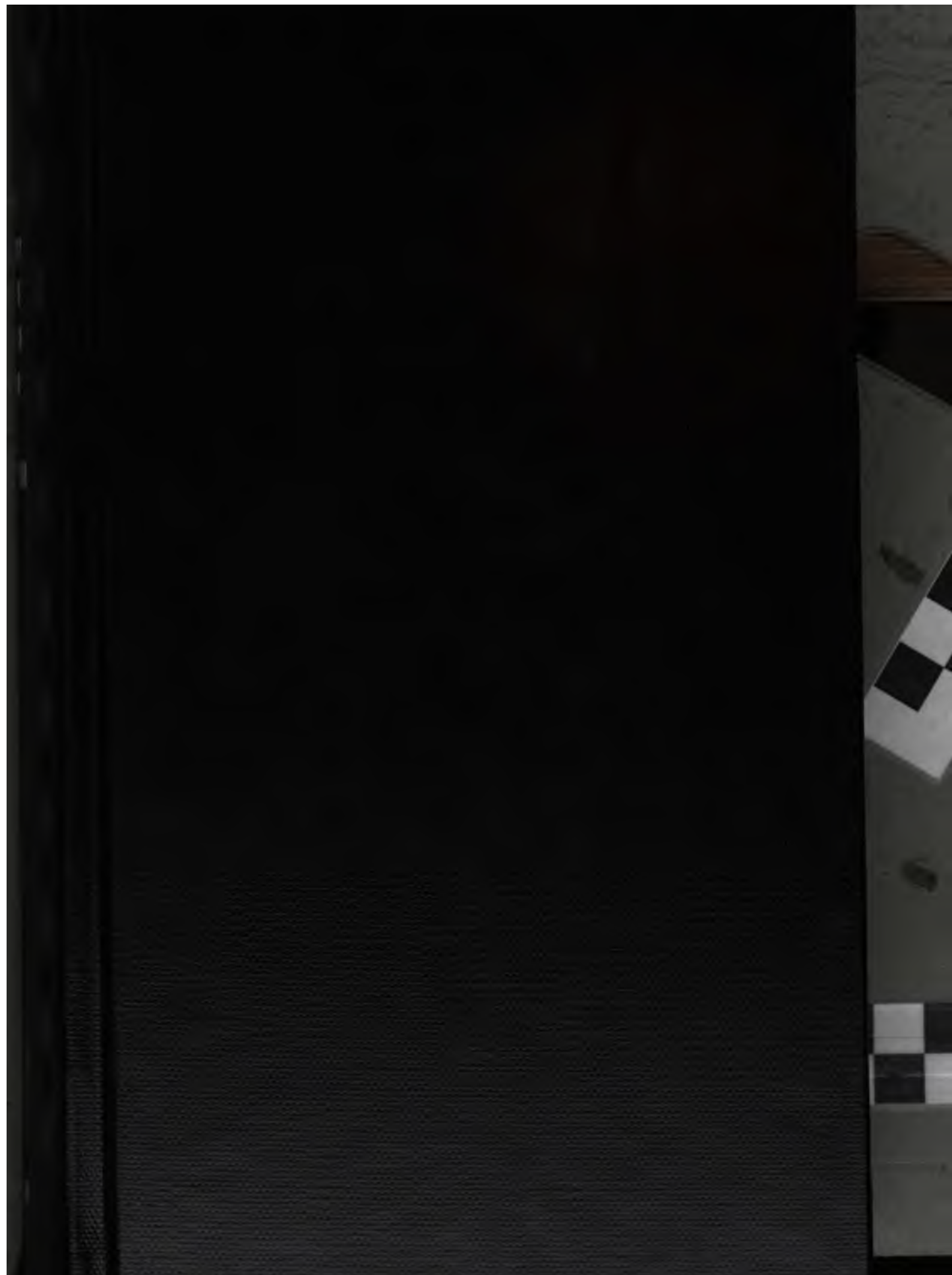
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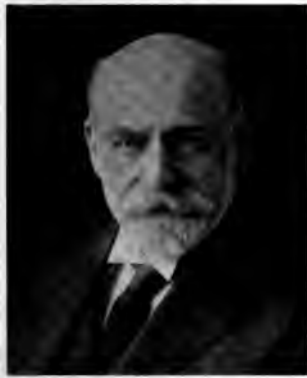
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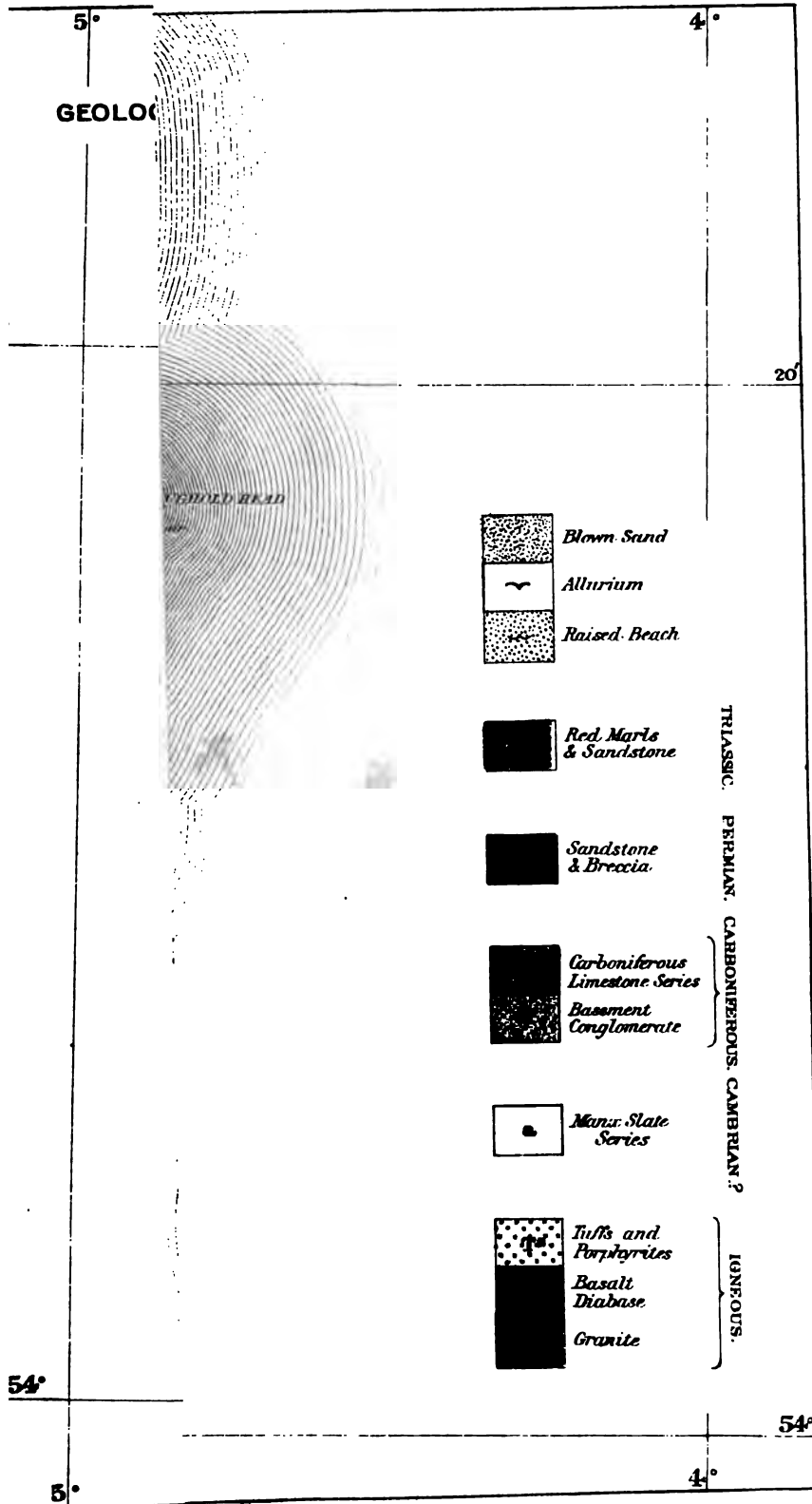




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MEMOIRS OF THE GEOLOGICAL SURVEY.
UNITED KINGDOM.

THE GEOLOGY
OF THE
ISLE OF MAN.

BY

G. W. LAMPLUGH, F.G.S.

WITH PETROLOGICAL NOTES BY PROF. W. W. WATTS, M.A., F.G.S.

~~~~~  
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PREFACE.

THIS Memoir, which, with the exception of the petrographical descriptions, has been wholly written by Mr. Lamplugh, embodies the results of his survey of the Island, which was commenced in 1892 and completed in 1897. The petrographical descriptions have been prepared by Professor W. W. Watts, who commenced the work during his tenure of office on the Geological Survey, but completed it after his retirement from the staff. Our thanks are due to Professor Watts for having so generously undertaken to complete this work under these conditions. The map was issued in 1898 in two editions, one with and the other without the drifts.

The work of the Survey in this, as in other districts, has been greatly facilitated by the labours of previous observers, and especially by those of the Rev. J. G. Cumming, whose long-continued and admirable researches are frequently referred to in the following pages. An outline of the geological literature relating to the Island is given in the second chapter.

As no previous account of the mines, beyond brief descriptions of the two largest mines in the Island, has been published, it was thought desirable to enter somewhat fully into the history and details of the mining industry. Through the courtesy of the Commissioners for Woods and Forests, it became possible, from documents in their possession, and especially from the manuscript reports of the late Sir W. W. Smyth, to give an authentic account of the numerous old workings, now abandoned and inaccessible, respecting which it is generally difficult to obtain any trustworthy information in the Island. It is hoped that this part of the volume will be found serviceable to persons connected with the mining industry and to students of the subject.

Our thanks are due to Dr. Wheelton Hind for great assistance in the palæontology of the Carboniferous rocks; to the Rev.

S. N. Harrison, of Ramsey, for the loan and gift of specimens from his fine collection of glacial shells, and for other friendly services; to Mr. A. W. Moore, M.A., Speaker of the House of Keys, and author of "A History of the Isle of Man," for notes on the ancient mines; to Mr. P. M. C. Kermode, of Ramsey, for much local information and ready help at all times; to Mr. H. Bolton, for permission to reproduce his description of the fossils of the Manx Slates; to the managers of the mines, throughout the Island, for their courteous assistance in obtaining information underground and for access to the mining plans, and especially to Captain J. Kitto, Captain W. H. Kitto, and Captain W. H. Rowe for particulars regarding old workings; to Messrs. Craine Bros., of Liverpool, and to Mr. J. Todd, the engineer-in-charge, for full information in respect to the deep borings in the north of the Island and gift of specimens; to Sir Archibald Geikie, to the Council of the Geological Society of London, and to Professor W. A. Herdman for permission to reproduce illustrations.

The Memoir is a record of the state of our knowledge of the geology of the Isle of Man, based on the work of previous observers and on that of the Survey. The chapters printed in large type give a consecutive account of the leading features of the geology of the Island, while the chapters or portions in smaller type contain the details, which are principally of local interest. This method has given rise to a certain amount of repetition; but it is hoped that the Memoir will have been thus rendered more convenient both to the general student and to the local worker.

J. J. H. TEALL,
Director.

*Geological Survey Office,
28, Jermyn Street, London,
22 September, 1902.*

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THE GEOLOGY OF THE ISLE OF MAN.

PART I.—INTRODUCTORY.

CHAPTER I.

GENERAL DESCRIPTION OF THE ISLAND.

"Rising from the middle of the Irish Sea, within sight of each of the three Kingdoms, with a history and associations so distinct, yet so intimately linked with those of the rest of Britain, this interesting Island presents in its geological structure features that connect it alike with England, Scotland and Ireland, while at the same time it retains a marked individuality in regard to some of the rocks that form its framework." These words, with which Sir Arch. Geikie preludes his account of the volcanic rocks of the Isle of Man serve equally well as an introduction to its general geology.¹

The predominant feature in its stratigraphy is the central ridge of slate and greywacke, which seems to have constituted an insulated tract at as early a date as the beginning of the Carboniferous Period.² This prototype of the present Island appears afterwards to have been enfolded and obliterated by the sediments of later times; but with the progress of denudation the old ridge has once more emerged from beneath this mantle.

Its insular character is as well maintained in its physical as in its geological features. The erosive agency of the simple drainage system, descending radially to the sea from the central hill-range, together with that of the waves which surround it, is adequate to explain all the contours of its present surface. It must indeed frequently during its history have been reunited to the mainland by a continuous land surface; but at such times it probably still retained in some degree its characteristic individuality, and arose above the surrounding plain as a hilly tract with a self-contained drainage, although its streams may

¹ "Ancient Volcanoes of Great Britain," vol. ii. p. 22.

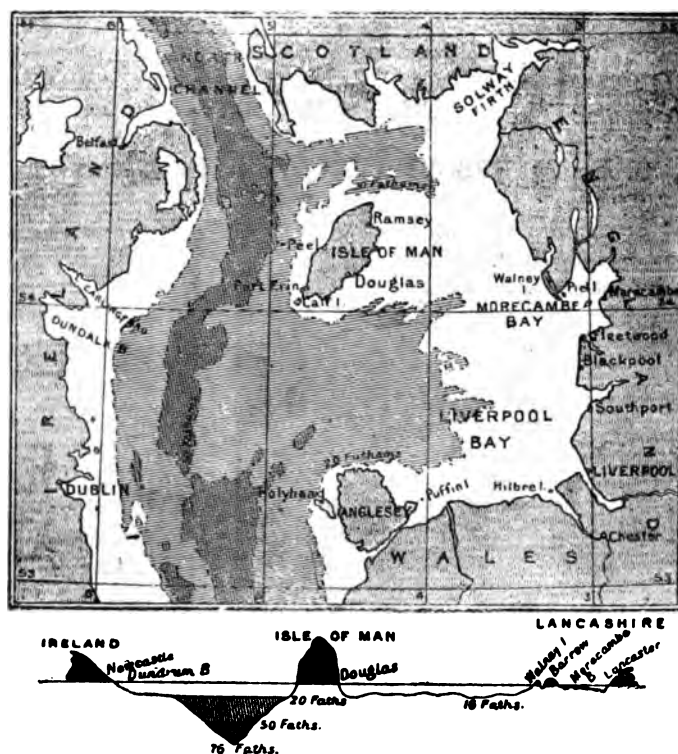
² See Rev. J. Cumming's "Isle of Man," p. 239; Rev. J. Clifton Ward *Geol. Mag.*, dec. ii., vol. vii. (1890), p. 6.

then have been tributary to a larger river-system lying beyond its limits.

The sketch map, Fig. 1, will serve to recall the position of the Island as regards the neighbouring shores. Its northernmost point is 16 miles distant from the nearest headland of the Scottish coast, while its closest approach to the Cumberland shore is 31 miles, to that of Ireland, in Co. Down, 31 miles, and to the Welsh coast near Holyhead 45 miles. The same map shows roughly the contours of the surrounding sea-bottom. To

FIG. 1. *Sketch Map and Section of the Irish Sea Basin.*

(PROF. W. A. HERDMAN, *Report Brit. Assoc.* 1896.)



the eastward of the Island the depth is nowhere more than 20 fathoms; to the northward it rarely reaches 30 fathoms; to the southward it usually ranges between 30 and 50 fathoms; while to the westward, midway to the Irish Coast, there is a long narrow trough descending to over 70 fathoms.

As at present constituted, the Island, with the detached islet of The Calf off its south-western extremity, contains 227 sq. miles (145,325 acres), of which 170 sq. miles, or three-fourths of the whole, are occupied by the slate and greywacke rocks, probably of Upper Cambrian age, composing the hilly massif. Strata of the Lower Carboniferous age occur in a small basin of 7 or 8 sq.

miles at a low elevation in the south of the Island ; and a narrow strip of red sandstone, probably belonging to the same period, borders the coast for two miles about midway upon the western side. The northern extremity consists of a low-lying tract of about 45 sq. miles, which is an addition made to the Island in Glacial times by the deposition of great masses of Glacial Drift upon the Pre-glacial sea-floor. Deep borings through this drift have recently revealed a rock-floor of Triassic, Permian and Lower Carboniferous strata at a considerable depth below sea-level.

The Island is irregularly oblong in shape, with its longer axis running N.N.E. to S.S.W., which is the direction of strike of the slate-rocks. In this direction, from the Point of Ayre to Spanish Head the land has a length of 30 miles, while the breadth of its wider central portion varies from 8 to 12 miles. Excepting in the well-cultivated northern plain, there is little flat ground. In the interior the physical features bear much resemblance to the Southern Uplands of Scotland. The hills are steep, but not generally craggy, and are arranged in long grassy or heather-covered ridges running with the longer axis of the Island, with broad intervening valleys. The highest of these ridges commences in the vicinity of the eastern coast near Ramsey, and is practically continuous to the south-western coast north of Port Erin, but is broken across in one place by a deep transverse valley, which intersects the Island between Peel and Douglas. North Barrule, with an altitude of 1,840 feet, forms the north-eastern extremity of this ridge, which culminates $3\frac{1}{2}$ miles farther south-westward in Snaefell, the highest point of the Island, with an elevation of 2,034 feet, while Cronk ny Arrey Lhaa, overhanging the south-western coast, is 1,449 feet in height.

Most of the larger streams of the Island rise in the vicinity of Snaefell and fall outward in different directions to the sea, the Sulby River and Glen Auldyn water draining northward, the Cornah and the Laxey Rivers eastward, the Glass and the Baldwin south-eastward, and the Neb south-westward. The drainage of the smaller tract south of the transverse valley is radial from a separate centre in the south-western portion of the hill-chain, whence flow the Glen Rushen waters north and north-westward, the Foxdale River northward, and the Santon, the Silverburn, and the Colby southward. Fuller details of the physiography are given in the small-typed portion of this chapter.

The Ordnance one-inch map of the Island, though numbered in the New Series as occupying sheets 35, 45, 46, 56 and 57, is published at present only in a single sheet (No. 100 of the Old Series).

The following Table of Strata shows the divisions which have been adopted for the one-inch map of the Geological Survey, published in 1898. The more southerly portion of the northern drift-plain may possibly be underlain by rocks intermediate in age between the Manx Slate Series (Upper Cambrian ?) which bounds it on the south, and the Lower Carboniferous strata which have been proved in the borings at its northern margin.

But in the complete lack of evidence as to the character of its rock-floor in the intervening tract, and in view also of the absence of intermediate strata where the base of the Carboniferous system is seen in outcrop in the south of the Island, it would have been rash to introduce into the map any divisions not yet actually proved to exist within the area. Hence the conjectural lines by which an attempt has been made to express on the map the solid geology of the buried rock-floor are based on the assumption that no other formations are present therein than those which have already been proved to exist.

TABLE OF STRATA.

RECENT	-	-	{ Blown Sand. Peat - - - Alluvium - - Raised Beach - Marine.	Freshwater.
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GLACIAL	-	-	{ Late-glacial Flood-gravels. Sand and Gravel occurring as platforms. Sand and Gravel occurring as mounds. Boulder Clay or Loam, and Rubble Drift.
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Great Unconformability.

TRIASSIC	-	-	{ Red Marls (saliferous) St. Bees Sandstone. - -	Proved in deep borings beneath the drift- plain.
PERMIAN	-	-	Lower Marls and Brockram	

Great Unconformability.

CARBONIFEROUS	-	{ Carboniferous Limestone Series. Basement Sandstone and Conglomerate.
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Great Unconformability.

UPPER CAMBRIAN?	{	Manx Slate Series	Locally divided into	{ Barrule Slate. "Crush Conglomerate." Agneash and other Grits. Lonan and Niarhyl Flags
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Contemporaneous.

	Carboniferous	-	{ Tuff, Agglomerate, &c. Basalt.
	Manx Slate Series?	{	Tuff (<i>small patch near Dalby only</i>).
	Intrusive.		
IGNEOUS ROCKS	-	{ Olivine-Dolerite (Tertiary ?) dykes. Diabase, etc., ("Greenstone") dykes. Diabase, Epidiorite, Chlorite schist, etc., ("Altered Greenstone") dykes. Diorite and Camptonite dykes. Mica-trap dykes. Micro-granite dykes. Granite.	

DETAILED DESCRIPTION OF THE PHYSICAL FEATURES OF THE ISLAND.

The Raised Beach.

Commencing our examination at the northern extremity we find first a barren strip of shingle, rising from 10 to 15 feet above high-water mark, covered in places with low dunes of drifting sand. This tract, known as The Ayre, has a width in its eastern portion, at the Point of Ayre, of $1\frac{1}{2}$ miles; but narrows gradually westward, until on the opposite side of the Island, in the vicinity of the Lhen, about 6 miles from the Point of Ayre, it has dwindled to a mere bank like a single storm beach. Throughout the greater part of its extent the inner margin of this old beach is sharply defined by an ancient cliff carved out of the drift deposits, the slope of which in many places is nearly as steep as that of recent cliffs of the same material. At Blue Point, near the western termination of The Ayre, the summit of this old cliff is about 100 feet above Ordnance datum. The prevalent belief of the countryside (which has found its way into the topographical literature of the Island) based no doubt on the fresh aspect of the bare shingle-ridges, is that The Ayre is still growing by accretions to its seaward margin. The present investigation, however, has shown that this view is almost certainly erroneous. Not only has there been no addition to the land at the Point of Ayre during the last 85 years (see p. 417), nor in any part of the tract since the Ordnance Survey was made 30 years ago, but also in some places there are clear indications that encroachments have been made by the sea upon the raised beach since its accumulation, the old shingle-ridges near the Point of Ayre being broken off abruptly by the present shore and the recent storm-beach lying athwart them.

In many other places around the sea-margin of the Island less conspicuous indications of the same raised beach are found. Thus, the older portions of the towns of Ramsey, Laxey, Douglas, Castletown and Peel stand on a corresponding marine terrace, slightly above present high-water mark; and elsewhere the innermost recesses of the bays, inlets and caves with which the rocky coast-line is abundantly indented are often above the reach of the highest waves of the present sea, so that their erosion is arrested. Even the outstanding headlands frequently still exhibit, above high-water mark, the notch which was cut into them during the same period of depression. The persistence of this notch is a striking indication of the durability of the slate-rocks, as well as of the comparative recency of the re-elevation of the land. From evidence which will be given in a later chapter (see p. 403) it appears probable that this elevation was in progress during Neolithic times.

The Drift Plain of the North.

To the southward of the Ayre the drift-plain is diversified by a crescentic chain of mounds composed of glacial deposits, known as the Bride Hills, which in their higher eastern portion attain from 200 to 300 feet above sea-level, or about 150 feet above the general level of the plain. The western horn of the crescent, broken across by two wide drainage hollows, is traceable southward until it abuts upon the solid mass of the Island to the westward of Ballaugh. The eastern horn was probably once similarly continuous up to the hills in the vicinity of Ramsey, but has been partially destroyed by the encroachment of the sea, which eats with great rapidity into the incoherent drift-material of the mounds. The origin of these mounds will be discussed in the later chapter dealing with the Glacial Deposits. On the inner or concave side of the crescent the ground falls away to lower levels in a series of sloping platforms with terrace-like edges, until the boggy depression of the Curragh is reached, which lies immediately beneath the bold slopes in which the solid mass terminates northward.

The Curraghs.

Artificial drainage has rendered the greater part of this hollow cultivable, but it still contains some patches of bog and moist meadow-land which are sometimes flooded. Old records and maps¹ prove the existence of small bodies of fresh water in this area within historic times. In its earliest stages, about the close of the Glacial Period, the whole depression was probably filled by one continuous lake, fed by the streams descending from the hills; but somewhat later the water-level was lowered by the erosion of drainage-channels through the drift-barrier, and at least three separate basins at different levels were then revealed, falling towards the east, and more or less separated from each other by ridges of dry land. Hence we find that the height of the present surface of the most westerly portion of the Curragh, between Sulby and Ballaugh and to the north-eastward of Sulby, is from 36 to 40 feet, while that of the eastern portion, in the parish of Lezayre, is not more than from 18 to 25 feet, above ordnance datum. The presence of large trees embedded in the peat of the Curragh in several localities (see p. 439) affords further proof that the area has not been continuously flooded.

The high rim of drift around this depression caused the Post-Glacial drainage of the greater part of the northern plain to flow inland to the hollow, and the waters escaping thence to the sea have cut the above-mentioned gaps in the barrier. From the rapidity with which the drift-material could be eroded, some curious changes and reversals of drainage have been brought about in this area in Post-Glacial times. These will receive consideration on a later page. In many respects the district resembles the Holderness plain in East Yorkshire, which is similarly built up of drift-deposits piled upon a Pre-Glacial sea-floor.

The Northern Hills.

The northern termination of the solid massif of the Island has evidently once formed a coast-line. The range of bold rocky bluffs overlooking the drift-plain, broken only by the embayments at the mouths of the mountain valleys, bears all the characteristics of an old sea-margin; and though in places degraded, its upper slopes are frequently as steep as the slopes overlooking the cliffs of the present coast. The bluffs truncate the strike of all the component members of the Manx Slate Series, and do not coincide with any known structural feature of the rocks. In short, their whole aspect suggests a cliff-line, rising above the platform of marine erosion now buried beneath the Glacial and Alluvial deposits of the plain.

This likeness to a coast is recognised in the Manx place-names, the more prominent bluffs, like the headlands of the existing sea-margin, being known as Gobs, thus—Gob y Volley, etc. The feature is well expressed by the shading on the Ordnance one-inch Map, while on the Geological Map it is further accentuated by the ending off of the superficial deposits at the foot of the slope.

The upland ridges of which these bluffs are the termination attain an altitude of about 800 feet above sea-level, and are continued backward at this elevation into the high moorlands which form the northern portion of the massif of the Island. From their flatness and coincidence in altitude, these ridges appear to be the remnants of an ancient peneplain out of which the existing valley system has been carved; and the higher summits of the massif, which rise above them, appear to be the relics left from the destruction of a still older upland. The same 800-feet plateau seems also to have existed in the more southerly portion of the massif, though now almost obliterated. At any rate, in almost every part of the upland tract the surface-features of two distinct epochs of erosion may be recognised. During the earlier of these, the broad smooth outlines of the more elevated

¹ See Cumming's "Isle of Man," p. 215 et seq., & pl. iv., reproducing a map of 1595.

areas, with their wide but shallow drainage basins, were shaped out; while in the later, the excavating power of the streams was greatly increased, so that deep, steep-sided trenches were notched out in the lower portions of the old basins, and the gradients of the tributary brooks thereby sharply raised. As to the geological age of the earlier of these epochs it is not possible to speak with certainty; but from the manner in which the latest basaltic dykes of the Island, supposed to be of Mid-Tertiary age, are planed down along with the country-rock, a later Tertiary date seems to be indicated, at any rate for its final stages. The succeeding epoch of rapid denudation may be fixed with more confidence at the period immediately preceding the oncoming of Glacial conditions. The earliest drifts of the area have found lodgment within the trench-valleys, while from the sharpness of the contours, the interval between the erosion of the valleys and the deposition of the drift within them must have been comparatively short.

The Drainage of the Northern Hills.

Unlike the conditions on the northern plain, the drainage system of the hills has been scarcely at all modified by the Glacial Period. All the main valleys, and most of their branches, were already in existence in Pre-Glacial times; and though they must have been temporarily obliterated by the ice-sheet under which the Island was buried during the period of maximum glaciation and were in many cases made the receptacles of glacial deposits of considerable thickness, their general gradients were not materially affected. Hence upon the disappearance of the ice, the streams resumed their previous courses and cut rapidly through the incoherent glacial detritus to the old rocky floor, leaving only terraces of drift in places to show the original extent of the infilling. There are, indeed, in a few localities rocky gullies within the main valleys where the Post-Glacial stream has temporarily lost its way in re-excavating its old channel, but these have not permanently affected the drainage. There are also a few channels cut into the slopes of the hills in places where there is little or no natural drainage under present conditions. These, as will be shown in a subsequent chapter, were probably excavated by streams flowing principally within or upon the ice-sheet, and are independent of the land drainage, either of Pre-Glacial or of Post-Glacial times.

In the northern part of the massif, as previously mentioned, the chief watershed is formed by the long ridge which culminates in Snaefell. The Sulby River, the largest stream of the Island, flows northward from the north-western slopes until it reaches the foot of the hills, where, in Pre-Glacial times, before the northern plain was in existence, it no doubt discharged directly into the sea. Upon the recession of the great ice-sheet, it seems to have poured for some time into the western Curragh, and thence through the Lhen, a broad valley excavated through the drift-mounds (see p. 435), to the sea at the north-western angle of the Island. But at a later date it diminished in volume until no longer able to surmount its own flood-gravels, and by these has been deflected into its present easterly course under the range of bluffs. Here it is joined by the originally independent Glen Auldyn stream which flows northward from the more easterly part of the hills; and the combined waters now find their outlet on the east coast at Ramsey.

The opposite or south-eastern flank of the ridge is drained by the Cornah and Laxey rivers, which flow in deep Pre-Glacial glens, diverging respectively north-eastward and south-eastward, to the eastern coast. Before reaching the sea the Cornah stream turns sharply southward, and runs in a deep rocky glen of newer aspect than the upper portion of its valley, possibly indicating its "capture," during the Pre-Glacial elevation, by a small stream draining southward, with a very steep gradient, to the coast.

In the neighbourhood of Maughold Head we find a short segment, about $1\frac{1}{2}$ mile in length, of a broad Pre-Glacial hollow, truncated by the present coastline at Port e Myllin on the north and at Port Moar on the

south, indicating that an old drainage system has here been broken up by the encroachment of the sea.

The southern prolongation of the Snaefell ridge forms the gathering ground for the Glass and the Baldwin, which run southward in parallel valleys for 4 miles, and then uniting swerve south-eastward to their junction with the Dhoo in the central valley of the Island a mile to the westward of Douglas.

In the south-western continuation of the ridge towards the central valley the chief summits south of Snaefell are Beinn y Phott (Pen-y-Pot), 1,772 ft.; Garraghan, about 1,600 ft.; Colden, 1,599 ft.; Slieau Ruy, 1,570 ft., and Greeba 1,383 feet. The small streams flowing westward from Colden and Slieau Ruy unite to form the River Neb, which goes southward to the central valley at St. John's, and then westward and finally northward to the sea at Peel.

The north-western flank of the massif is occupied by an outer hilly ridge, parallel to but divided from the Snaefell chain by the broad basin of the Sulby River, having for its chief eminences Slieau Curn, 1,153 ft., Slieau Freoaghane, 1,602 ft.; and Sartfell, 1,560 ft.¹ The northern end of this ridge is cleft by Glen Dhoo, the short deep valley of a small stream which flows northward through the village of Ballaugh and the western edge of the Curragh. There is also a broad shallow depression on its western flank, continuing south of Kirk Michael for over three miles, which may possibly mark a once continuous line of drainage belonging to the older epoch of erosion, though its waters are now carried off by three separate streams, the most northerly flowing north and north-west to the sea at Kirk Michael through Glen Wyllin, the second running a parallel course to the sea at Glen Mooar (Michael), while the third goes southward to join the Neb below Glen Helen. The student of physiographical evolution will find in this portion of the Island some other features of peculiar interest, which will be discussed in the chapter on Glacial geology (see p. 363).

The Central Valley.

The deep central valley which runs across the Island from Peel to Douglas, since it affords an easy route bisecting the massif and separating the northern from the southern hills, has been noticed by all writers on the physical features of the country, and deserves our careful study. The first impression one receives upon examining it is that it is an antecedent feature, of high antiquity and independent of the general drainage system of the Island, due to conditions which may have prevailed at some period when the district has formed part of a larger land area. But this impression is dispelled by closer investigation, which reveals the probability that the gap has been caused by the breaking down of a ridge between two overlapping streams running respectively east and west from the central axis.² The head of the ravine draining eastward is still intact at Coollingill on the southern side of the valley west of Crosby; and the westward stream has probably had its source on the opposite side of the depression, in the comb-like hollows on the eastern flank of Greeba mountain, and has flowed round the southern end of that mountain, held in on the eastern side by a low ridge, since broken away, separating it from the former stream. Hence we may regard the gap which breaks the central ridge of the Island between Greeba and the craggy hill facing it on the south as principally the work of a westward-flowing stream now abolished. At present the main watershed of the Island lies about a mile to the westward of this gap, in the boggy bottom of the valley barely 160 feet above sea level: but this is clearly a case of captured drainage through the shifting back of the head-waters of the east-flowing stream. Close to

¹ Approximate only: height not stated on Ordnance map.

² We find that this explanation has been previously suggested, in a single sentence in a paper by Mr. J. White; "Remarks on the Geology of the Isle of Man." *Trans. Geol. Soc. of Glasgow*, vol. vii. (1882), p. 84.

this watershed two small streams discharge from the hills into the central valley from opposite sides—the Greeba River on the north and the Ballacurey or Glen Darragh stream on the south; and in Pre-Glacial times these have both been branches of the westerly drainage-system. But at the present day, while the second stream still goes westward to Peel, the first turns eastward through the Greeba Gap and, joining the Coillingill water, flows to the sea at Douglas. Their present channels in the valley near the watershed are, it is true, to some extent artificial; but the main cause for their divergence in opposite directions is the position of the fans of flood-gravel which the swollen streams have spread out at their debouchure into the central valley in Late-Glacial or Post-Glacial times. Each diminished brook now turns aside from its former gravelly fan and continues along the trunk valley at right angles to its previous direction; and the accident therefore which has sent them in opposite directions to the sea is a slight difference of trend before leaving the hills, which has determined the situation of the bar at their mouths.

The central valley has, no doubt, been modified considerably during the Glacial Period, and especially during the closing stages, when it seems to have been occupied by temporary bodies of fresh water hemmed in by the waning ice-sheet; but that it was mainly excavated, in the manner above-described, previous to the Glacial Period is shown by its general characters. From both sides of the Island it narrows towards the centre, and has the sinuous course characteristic of fluvial action. So far as can be observed, it cuts across the Slate Series without reference to their structure, like the other transverse streams of the Island. Its present floor rises gradually from sea-level at Peel and at Douglas to about 160 feet above sea-level at Greeba; and though the rock-floor is buried beneath drift and alluvium throughout its course, the general aspect of the rock-slopes of the valley suggests that the gradient of this floor corresponds in the main to that of the infilling material. Its erosion may indeed have been facilitated in one portion of its course westward of Greeba by certain peculiarities of rock-structure to be described in a later chapter (p. 52), which have tended to produce a somewhat more rapid weathering of the slates and therefore a general lowering of the surface; and its westerly termination nearly coincides with the faulted western margin of the Peel Sandstone; but, considered as a whole, in spite of its unique character among the valleys of the Island, we conclude that it may be explained as a combination of two simple valleys of erosion essentially similar in origin to the other valleys of the country.

The Southern Hills.

On the southern side of the great valley both the central and western hill-chains are continued, though of less elevation than in the northern area. Slieau Whuallian, 1,054 ft., and Dalby Mountain, about 950 ft., are the chief eminences of the western ridge, and South Barrule, 1585 feet, of the central; and the two converge southward and unite in Cronk ny Arrey Lhaa, 1,449 feet, immediately overlooking the western coast. To the eastward, lower hills extend to the coast-line in the district occupied by the Manx Slates, but towards the south the ground falls away into a drift covered lowland country of limited extent, which is underlain by the Carboniferous rocks. Southward from Cronk ny Arrey Lhaa, lower hills of slate form the western margin of this Carboniferous basin, and are prolonged into the Calf of Man. This islet is a little less than one square mile in extent, and its highest point is 421 feet above sea-level.

Excepting in the ground to the westward of the ridge of South Barrule, the drainage of this area flows southward or south-eastward to the coast, in brooks of which the chief are the Santon River, the Silverburn, and the Colby River. These streams run for the most part in shallow open valleys, and not in deep-walled glens like the majority of the Manx mountain streams. Their courses often present examples of local modification from the effect of the Glacial deposits with which the valleys are partly choked (see pp. 468–70).

The drainage of the depression between the South Barrule ridge and the Slieau Whuallian and Dalby Mtn. ridge is somewhat curious. Its higher southern portion, where the ridges unite, forms the gathering ground for a small river which flows north-north-eastward along it for two miles, occupying an inner hollow known as Glen Rushen. The stream then turns sharply at right angles to its former course, and goes west-north-westward, cutting through the Slieau Whuallian range in Glen Mooar, a deep Pre-glacial valley about a mile in length, and thence passes westward into Glen Meay, a smaller Post-glacial ravine, by which it reaches the western coast nearly 3 miles south of Peel. Between Glen Mooar and Glen Meay the stream captures a tributary from the south which seems once to have flowed northward to the Neb through a valley now dry, along which the high road goes from Dalby to Peel.¹

The depression of which Glen Rushen forms the southern part is prolonged north-eastward from the point where the Glen Rushen stream escapes from it, a low watershed dividing its drainage between Glen Rushen and Foxdale. In this case the Foxdale drainage appears to be encroaching upon that of Glen Rushen. Foxdale is a deep Pre-glacial valley which carries the waters from the north-eastern slopes of South Barrule northward to the Neb at St. Johns. That it is an aggressive stream and is appropriating the drainage of its neighbours is further shown at its head, where its two branches have trenched respectively upon the sources of the Santon River and the Awin Ruy, a tributary of the Silverburn; and it has moreover been artificially assisted in capturing drainage by a sluice which has been cut on the southern slope of South Barrule to bring more water to the reservoirs of the Foxdale Mines.

The aggressiveness of this stream probably dates back to the elevation of the land in Pre-glacial times, its shorter course and consequently steeper gradient then giving it the advantage over its longer and more leisurely rivals. Other cases of the same kind may be studied in the central district north of the main valley, and the above descriptions may serve as generally typical for the stream-development of the hilly part of the Island.

Present inactivity of the Manx Streams.

There is clear evidence in every part of the Island that the volume of the streams has greatly diminished during comparatively recent times, and that their present condition is one of relative inactivity as regards their erosive power.

The trenches cut into the drift deposits at the heads of the brooks, both in the mountains and on the lowland, are now usually dry and overgrown with grass, or are even becoming refilled with peaty growth, while lower down the valleys the stream-channels are often choked with coarse detritus beyond the power of the present waters to remove. The relative weakness of the existing Manx streams is also noticeable when they are compared with those of other areas of similar physical character, as, for example, with those of some parts of the English Lake District where the drainage, though shrunk from its former volume, is still doing vigorous erosive work.

These facts no doubt indicate changes of climate by which there has been a diminished and more evenly distributed rainfall, and less snow in the winter.

The total annual precipitation for the last twenty years varies

¹ Reference to the hill-shaded one-inch map will serve at a glance to elucidate this description, and also the previous account of the central valley.

from about 60 inches in the hills, to 25 to 30 inches on the plain,¹ which is less than the island might seem to claim from its geographical position and average altitude.

The force of the streams would probably be materially increased by a comparatively small additional rainfall, since the retentive power of the soil and vegetation on the valley slopes, though very effective up to a certain point, is lost when the saturation limit is reached; so that any excess of rainfall above the quantity requisite to produce this condition is shed at once into the streams and tends to produce powerful floods. But when, as at present in the Isle of Man, the precipitation is fairly evenly distributed throughout the year, and rarely sufficiently rapid to produce saturation, the water reaches the drainage channels so gradually that the streams, though constant, are persistently feeble. The great fans of flood-gravel which often mark the issue of the Manx hill-streams upon the plain betoken past conditions very different from those which now obtain (see p. 371).

The Coast-line.

Not only from its extent but also from its wide diversity of character, the coast line is, as might be anticipated, of extreme interest to the physiological student. The low Ayre beach along its northern margin has already been described. To the southward, fringing the drift-plain, are high cliffs composed entirely of Glacial clay, sand and gravel, which crumble rapidly beneath the attack of the waves. So rapid is the encroachment of the sea upon these cliffs that the annual recession of the land in some parts of the parishes of Jurby and Michael, on the western coast, reaches an average of 4 feet (see p. 13). Where boulder clay enters largely into their composition these cliffs are occasionally precipitous; but more frequently they present long talus slopes, from the falling away of the loose stratified material which is generally their chief ingredient. On the eastern coast they stretch southward from the Ayre for 6 miles, usually between 50 and 90 feet in height, but rising to over 200 feet at Point Cranstal where they intersect the Bride Hills. On the western side of the Island they

¹ Mr. A. W. Moore, Speaker of the House of Keys, to whom our knowledge of the meteorology of the Island is principally due, gives the following observed averages of rainfall for the twenty years 1878-1897:—

Point of Ayre - - - - -	24·6 inches.
Cronkbourne (near Douglas) - - - - -	41·1 "
Calf of Man - - - - -	24·6 "

He has also kindly furnished me with the following figures calculated for the same period at other localities where observations have been carried on for less than this time:—

	Period of observation.	Actual fall.	Calculated mean for 20 years.
Druidale - - - - -	2 years.	61·1	60·6
Peel - - - - -	5 "	35·5	38·1
St. Marks - - - - -	6 "	35·5	39·5
Ballasalla - - - - -	7 "	30·3	27·5
("Gauge probably in too sheltered a spot.")			
Port Erin - - - - -	3 "	31·7	33·
Andreas Rectory - - - - -	6 "	32·4	35·1
Langness - - - - -	10 "	26·9	26·1

See also Mr. Moore's "Climate of the Isle of Man." (Douglas, Brown and Son. 1889.)

extend for eight miles, with an average altitude of about 80 feet, the solid rocks making their first appearance in the cliff $1\frac{1}{2}$ miles to the southward of Kirk Michael.

The tidal flat beneath these cliffs is everywhere broad and sandy, dotted here and there with large boulders derived from the wasting drifts; and where the beach-material is locally stripped away by storms, a floor of red boulder-clay or pebbly loam is exposed.

The graceful contours and cheerful colouring of these cliffs render the natural scenery of this part of the coast very pleasing; while to the student of glacial geology these fine sections, by reason of their fossil contents as well as their exceptional height and extent, are of unusual interest.

To the southward of Ramsey on the east coast, and of Ballacarnane on the west, though the drifts still often form a thick capping to the solid rocks, the rugged dark-hued Manx Slates are the dominant factors of the scene.

These occur in jagged cliffs, whose outline varies according to the relation of the coast-line to the direction of dip of the slates. As the general strike of the strata is roughly parallel to the trend of the shores, and as the dominant structural dips are at high angles outward from an anticlinal axis in the interior toward the coasts, there is a prevalence of dip-slopes in the cliffs on both sides of the Island, which is, however, constantly interrupted by the coastal irregularities. The stratigraphical axis of the Slates is intercepted by the sea in the vicinity of Maughold Head in the north-east, and of Bradda Head in the south-west; and in the neighbourhood of these places the cliffs are characterized by rapid changes of lithological character, the various divisions of grit, greywacke and slate, which go to make up the Manx Slate Series, being contorted together and presented in swift succession; but in the middle portion of the Island the shores run principally amid the flaggy greywacke divisions—the Lonan Flags on the east, and the Niarbyl Flags on the west—so that the prevalent rocks of the cliff-sections are these alternately thick-bedded and thin-bedded gritty or slaty flags.

From the hilly character of the ground out of which they are carved, the cliffs vary greatly in altitude. They are not often precipitous from base to crest, their profile in most places exhibiting a long steep upper slope terminating in a shorter more nearly vertical wall below. The long slope appears to represent the degraded remains of the Pre-glacial coastal feature, while the shorter precipice at its foot marks the re-advance of the sea since Glacial times.

On the eastern side of the island, the boldest and most picturesque portions of the coast are Maughold Head, about 250 feet; Bulgham Bay, 600 feet; Clay Head, 300 feet; Douglas Head, 300 to 400 feet; and Spanish Head about 400 ft. in height. The Calf is surrounded by steep cliffs, and except in very calm weather there are only two places where it is possible to effect a landing upon it. The Chickens Rock, on which stands a fine lighthouse, is an insulated low-water reef, composed of the Manx Slates (see p. 173), lying off three-quarters of a mile to the south-westward of the extremity of the Calf.

Where the Carboniferous rocks of the southern area occupy the coast, the shore is broad and shelving and the cliffs low; and there is an absence of the jagged outlines which characterize the sea-margins of the older formation.

On the western side of the Island, the cliffs in the slaty rocks to the southward of Kirk Michael are comparatively low, but full of picturesque detail from their irregular erosion. These extend southward for $2\frac{1}{2}$ miles, and a fault then suddenly brings in the Peel Sandstones whose steep dip-slopes form a more regular sea-margin for the next two miles, up to the town of Peel. At Peel the slates reappear and are continuous thence throughout the western coast, forming bold cliffs, with scarcely any drift-capping excepting in the low tract between Glen Meay and Dalby and in the coves of Fleshwick and Port Erin. Near Contrary Head the ground neighbouring the coast rises to 500 feet; while to the southward of Dalby, where the cliff-line intercepts the principal hilly axis, it presents a mag-

nificent series of rudely terraced precipices plunging from the summit of Cronk ny Arrey Lhaa, 1449 feet above Ordnance datum, down to the sea. Thence to Bradda Head, a distance of 4 miles, the grandest cliff-scenery of the Manx coast is traversed, the crest of the declivity never sinking below about 650 feet except in the lovely recess of Fleshwick. The ground also falls away rapidly inland, so that the views from the summit over land and sea are delightful, including in clear weather, down on the western horizon, a long stretch of the north-eastern coast of Ireland, with the Mourne Mountains in the background.

Coast Erosion.

The following notes were drawn up by the writer in 1897, at the request of the late Deemster Gill, to be laid before a Committee appointed by the House of Keys to inquire into the coast erosion of the Island :—

"It was found during the course of the survey that the greatest loss had taken place in the parish of Jurby, where in some instances a span of 50 yards had disappeared since the Ordnance Map was made, 28 years before. Near Orrisdale the loss in the same period had been from 20 to 30 yards, and it had been about the same near Kirk Michael. Northward from Sartfield, in Jurby, there was practically no loss, as the cliff is protected by a low platform of shingle and blown sand continuous with the ancient sea-beach which forms The Ayre. This protecting platform evidently once extended farther southward, and is slowly yielding to the flank-attack of the sea. So long as it remains there can be no waste of the cliff behind it; and the idea prevalent in the north of the island, that the loss of land is greater now than formerly, probably has its basis in these conditions. The current impression, however, that The Ayre is still increasing is a mistaken one. (See pp. 402-3.)

"The removal of shingle is generally held to be detrimental to the preservation of the cliffs, but its effect must vary very much according to the local conditions. Where the cliffs are wasting rapidly the new material annually added to the beach must greatly exceed the quantity removed by human agency, and if the shore were left undisturbed it is probable that the shingle would still be carried down by tidal action. But where no new material is being added to the beach, the removal of the sand and gravel must be harmful by lowering the shore and increasing the power of the waves upon the cliff. In every case the larger boulders should be allowed to remain, as these are not readily washed away, and tend to accumulate at the foot of the cliff as a rude breakwater.

"The subject of Coast Erosion generally has been investigated by a committee of the British Association, and a large body of information from all parts of the kingdom has been collected and published in the annual reports of the Association, wherein many valuable hints as to the result of the removal of shingle and the effect of various kinds of protection-works may be gleaned.

"The district of Holderness in East Yorkshire furnishes a case exactly similar to that of the northern part of the Isle of Man. In both areas the land consists of loose deposits of sand, gravel and boulder clay, forming low tracts upon which the sea is steadily encroaching. In Holderness, along a coast line of about 35 miles the average loss is stated to be at the rate of 2½ yards per annum, though in some places the loss is as high as 5 yards per annum. Defences have been erected to protect the towns of Bridlington Quay, Hornsea and Withernsea, but no attempt has been made to preserve the purely agricultural land, as calculation has shown that the annual charge of any efficient scheme of defence would exceed the value of the land lost in the same period. This subject has been fully discussed from the standpoint of the engineer by Mr. R. Pickwell, C.E. In his paper on 'The Encroachments of the Sea from Spurn Point to Flamborough Head, and the Works executed to prevent the Loss of Land' (in Proc. Institute of Civil Engineers, vol. li., 1877-78), Mr. Pickwell considers that the coast might be efficiently protected by a system of timber groynes, 300 to 400 feet in length, and 300 to 400 yards apart, of which the cost would be approximately (in 1877) £1 10s. per lineal yard of protected coast.

"He then states that 'taking a length of 1,200 yards of coast and the loss at 2½ yards per annum, there is an actual loss of land of from three-quarters of an acre to one acre per annum, equal to £35 to £50 per annum. The interest alone on the cost of protective works, as suggested, for the same length of frontage, would be equal to £90 to £100 per annum, at five per cent., so that to the landowners as a whole it is cheaper to lose the land than to protect it.'

"The Memoir of the Geological Survey on 'Holderness,' by Mr. Clement Reid, contains full details of the loss of the land in Holderness."

Durability of the Manx Slate Series.

From their tough and well-knit character all the members of the Slate Series are very enduring under the attack of the sea. The cliffs are moreover protected in most places by the presence of a bare rocky tidal-reef ending off in deepish water, and by the consequent scarcity of the beach-material which is so powerful an agent in erosion. Hence the waves break with so little effect against the rocks that even during storms the water remains unclouded, except in the vicinity of the shingly recesses where there is sometimes a little rock-flour in suspension. Indeed we find that in these old rocks the coast-line of the Island, like the drainage system, has undergone only slight modification since Pre-glacial times. That is to say, the recession of the rocky part of the coast since Glacial times has not been sufficient to affect materially the outline of the old massif, and there are many indications that cliffs of the slate rocks were in existence in Pre-glacial times in approximately the same position as those of the present day. The rocky tidal shelf on the more exposed parts of the coast appears usually to represent the extent of Post-glacial erosion, while in some of the larger bays, *e.g.* those of Douglas, Port St. Mary and Port Erin, where the foreshore is broad and smooth there are patches of drift upon the rocky platform, apparently indicating that even this feature may sometimes be Pre-glacial; and in a few sheltered recesses the ancient cliff-slope is still unbroken (see pp. 346, 446, 462).

The persistence in many places of the little notch which was cut into the base of the cliffs during the Raised Beach stage, already commented on, affords another illustration of the slow progress of marine erosion. This quality of the mass of the strata serves to accentuate the effect of the sea upon every plane of weakness in the massif; and the coastline is therefore gashed by innumerable narrow gorges and partially roofed recesses, marking the lines along which the rock is dislocated and somewhat shattered (see p. 86). These in some parts of the Island are known as Gulleys; in others as Ghaws—the latter a term of Norse derivation, in common use in Iceland for similar features. Where these channels intersect, rude rock pillars or Stacks are isolated, which stand like sentinels a little in advance of the main cliff-line. These are the favourite haunts of sea-birds. Wider recesses named Purts or Ports occur at intervals; and in them, as in the more open bays, there is usually some

accumulation of beach-material, which in Manx is called the Traie.

Other physical details regarding the coast will be mentioned in the account of the stratigraphy of the cliffs in succeeding chapters.

Sub-aerial weathering of the Manx Slates.

It sometimes happens that rocks which offer a firm resistance to the sea, are yet crumbled away readily by the less boisterous but more subtle sub-aerial agencies. This is not, however, the case with the Manx Slates, which appear to give way as slowly to the one attack as to the other. In no part of the series are the rocks in themselves permeable to water, so that it is only along the lines of jointing and faulting that underground percolation can take place in them, and the sparsity and insignificant size of the rock-springs show that the amount of water thus conveyed must be very limited. The structural changes, due to pressure and earth-movement, which the strata have undergone, while often obliterating the tendency to split along the bedding planes, have not usually developed a sufficiently definite cleavage to render the rock readily fissile in any other direction. The result is especially notable in the argillaceous portion of the series, which has been so toughened and welded into one mass that, though intrinsically much softer than the greywackes and grits, it is much less jointed and less liable to splinter, and has therefore resisted disintegration better. Hence we find that the higher ridges of the Island, with all its chief eminences, are principally composed of the comparatively soft argillaceous Barrule Slates, while the hard Agneash Grits, with the Lonan and Niarbyl Flags, for the most part occupy lower ground on their flanks.

The granitic bosses also form comparatively low ground in the massif, and the intrusive igneous dykes with which the sedimentary rocks are often riddled are rarely prominent at the surface.

The persistence of the old massif as a land area is evidently due to this enduring quality of its component strata.

As a general rule, it has not been found that the valleys of the Island bear any relation to the stratigraphy of the present surface; but there are certain exceptions in which, on a limited scale, some such relationship may exist, as, for example, where Sulby Glen follows for some distance the main belt of Crush-conglomerate, and where Glen Agneash coincides for a short space with the outcrop of the Laxey metalliferous lode.

CHAPTER II.

OUTLINE OF THE LITERATURE.¹

Preceding the more strictly geological literature of the Isle of Man, we find in various early topographical accounts the usual desultory scraps of geological information. Governor Sacheverell, for example, in his "Account"² published in 1702, refers to the mines of Lead, Copper and Iron³; and to the occurrence of trees interred in the bogs of the Curragh, of which he notes that they are discovered by reason of no dew resting on the ground above them.⁴ He mentions also a mineral spring or pool in Kirk-Christ Rushen "of vitriolic quality . . . which probably proceeds from the frequent spewings of copper, that are discovered on all sides of these mountains."⁵ Governor Waldron's account printed in 1731,⁶ in spite of the reference in the sub-title to "Minerals," deals with the superstitions of the people rather than with the natural features of the Island. Bishop Wilson wrote a description for an edition of Camden's "Britannia" published in 1772, afterwards reprinted in the collected edition of his works.⁷ He mentions that in the Curragh where bogs had been drained and brought under husbandry, very large trees of oak and fir were found, "not promiscuously, but, where there is plenty of one sort, there are generally few or none of the other"; also that the limestone rocks (Carboniferous Limestone) "especially about Bally-lool, are full of petrified shells of different kinds, and such as are not now to be found on these coasts." The red freestone (Peel Sandstone) around Peel, and the blue slate, which at Spanish Head was wrought in long beams of tough stone 12 to 15 feet long and "strong enough to bear the weight of the highest stack of chimnies," are also described; and in referring to the mines of lead, copper and iron, he notes also that no coal was found, though several attempts had been made to discover it. Some items of similar information may

¹ In Appendix iv., p. 588, will be found a full list of the geological literature; in the present chapter reference is made only to the more important contributions.

² "An Account of the Isle of Man, its Inhabitants, Language, Soil, Remarkable Curiosities" etc. etc., by W. Sacheverell, late Governor of Man, 1702. Reprinted by the Manx Society, vol. i., Douglas, 1859.

³ P. 17 of Manx Soc. reprint.

⁴ Ibid, p. 19.

⁵ Ibid, p. 18.

⁶ "The History and Description of the Isle of Man, its . . . Minerals," etc., by G. Waldron, London, fol. 1731, and 12 mo., 1744.

⁷ "The Works of T. Wilson, D.D., Lord Bishop of Sodor and Man," compiled by the Rev. C. Cruttwell, to which is added his "History of the Isle of Man." Bath, 1781.

likewise be found in Townley's book,¹ issued in 1791, and in that of Feltham, in 1798.²

The study of the geology of the Island may be said to have commenced with the publication of Woods' "Account" in 1811,³ though it appears that as early as 1801 William Smith had obtained sufficient information to enable him to construct a rough manuscript map of its rocks.⁴ Woods roughly classified and described the strata according to the then prevalent ideas as to "primitive" and "transition" rocks, and outlined their distribution in a small map which appears to be the earliest published geological map of the Island. In the central massif he recognized greywacke, clay-slate and mica-slate, resting on granite; and in the Carboniferous area transition-limestone and breccia. The sand and "common clay" of the northern plain and the peat of the Curragh were also observed, and attention was drawn to the presence of blocks of granite on South Barrule which have been so frequently discussed in the later literature. His description of the state of the mines is full and interesting, and his work, as a first sketch, has considerable value, though its scientific importance was dimmed by the more authoritative publications which followed soon afterwards.

In the following year Mr. T. Quayle published his "General view of the Agriculture of the Isle of Man," which contains much information regarding the rocks and soils of the island, and has for frontispiece a coloured "Map of the Soil," which is really a geological map.⁵

The next decade constitutes one of the most fruitful periods in the geological annals of the Island, its stratigraphy being independently made the subject of personal investigation by no less than three well-known members of the little band of British students of the new science, viz., Berger, Macculloch and Henslow.

To the student of Manx place-names these early geological treatises, in which the names of localities are phonetically spelt, may be recommended for the information they afford as to the old pronunciation, now in many cases obsolete and forgotten.⁶

Berger published the result of his investigations, illustrated by a geological map and sections, in 1814.⁷ In his classification,

¹ "A Journal kept in the Isle of Man, with observations on the Soil, Clime and Natural Productions," etc. Whitehaven, 1791.

² "A Tour through the Island of Mann, etc," by J. Feltham. Bath, 1798.

³ "An Account of the Past and Present state of the Isle of Man, including . . . a sketch of its Mineralogy" by G. Woods., London, 1811.

⁴ See Prof. J. W. Judd on "William Smith's Manuscript Maps," in *Geol. Mag.*, dec. iv., vol. iv. (1897), p. 447.

⁵ London 1812, 8vo., pub. by G. & W. Nicol.

⁶ *E.g.* Kreevey (Woods), now Greeba; Borroilva (Berger), now Barrule; Dhoođen (Henslow), now Dhoon.

⁷ "Mineralogical Account of the Isle of Man," by J. F. Berger, M.D. — *Trans. Geol. Soc.*, vol. ii. (1814), p. 29.

under the head of "Primitive Rocks" are placed "Granite" and "Clay-Slate"; under "Transition Rocks" "greywacke" (described as "thick-slaty," as compared with the "thin-slaty" clay-slate) of several varieties; and under "Floetz-Rocks," "limestone," "amygdaloid" (under which term the Carboniferous Volcanic series is indicated), and "Sandstone" (including the Carboniferous Basement Conglomerate of Langness and the Peel Sandstone). The details given in respect to these divisions are of unequal value and tinged with theoretical misconceptions, but are not wholly obsolete and may still be read with profit by the student of the Manx Slates. Besides the "Compound rocks *in situ*," Berger also describes at considerable length the erratic boulders, under the heading of "Compound rocks not *in situ*." His interesting historical notice of the minerals and mines has been largely made use of in preparing Chapter XIII. of the present work (see p. 482).

In 1819, Dr. Macculloch included a general account of the Island in the second volume of his great work on the Western Isles,¹ and appended a geological sketch-map and some plates of sections. His description of the physical characteristics of the area is admirable. He recognised that the greywacke and clay-slate formed one series, and comments frequently on the difficulty in distinguishing between the "fissile tendency" (cleavage) and the true bedding in these rocks. His outline of the stratigraphy corresponds in the main with that of Berger, but is fuller and better proportioned, and is illumined by many comparisons with the geology of Western Scotland.

In 1821, Prof. Henslow made a notable addition to the subject in a paper purporting to supplement and criticise that of Dr. Berger,² illustrated by sections and by a map which showed many improvements over its predecessors. This memoir is more purely geological than the previous contributions, the mines and minerals being scarcely mentioned, while the stratigraphy is described with a wealth of local detail which bears testimony to the careful character of the investigation. The two chief granitic areas of Foxdale and the Dhoon were for the first time accurately delineated, and the associated elvan dykes identified; the presence of "trap-tuff" as well as amygdaloid in the vicinity of Scarlet was demonstrated, and the relation of this material to the limestone discussed; the granitic blocks on South Barrule were recognised as having been transported, and the "diluvial matter" of the north more clearly defined; and the occurrence of remains of the Irish Elk in a fresh-water deposit at Ballaugh was described. In fact, after Henslow's labours we may regard the main outlines of the geology of the Island as having been established upon an accurate basis, which has served

¹ "A Description of the Western Islands of Scotland, including the Isle of Man," etc., by John Macculloch, M.D., 3 vols., London, 1819.

² "Supplementary Observations to Dr. Berger's Account of the Isle of Man," by J. S. Henslow — *Trans. Geol. Soc.*, vol. v. (1821), p. 482.

for all the superstructure of detail raised by subsequent investigations.

A rather acrimonious correspondence between Berger and Henslow followed the publication of this paper, the references to which will be found in the Bibliographical Appendix (p. 588).

With the exception of some short notes relative to the discovery at Ballaugh of the fine skeleton of Irish Elk now preserved in the Edinburgh Museum, between 1821 and 1825, and brief papers on the shells of the Glacial deposits in 1841 by Edward Forbes (who was a Manxman by birth), and in 1843 by H. E. Strickland, no noteworthy addition was made to the literature until 1846, when the Rev. J. G. Cumming began to publish the results of his observations.

Cumming was for some years the Vice-Principal of King William's College, at Castletown; and he made excellent use of the opportunities afforded him for acquainting himself with the detailed geology of the complicated Carboniferous basin of that district. It is only after a close survey of this area that one can appreciate to the full the acumen and thoroughness which distinguish all the work of this investigator. But while the Carboniferous rocks of the South and the drifts of the Island generally were the chief objects of his attention, his observations in every division of its stratigraphy were careful and valuable. His papers published in the Quarterly Journal of the Geological Society for 1846 and 1847¹ were accompanied by more detailed geological maps and sections than had hitherto been attempted, and in 1848 he issued a descriptive work on the Island,² in which its geological features received full treatment. Later papers of less consequence came from his pen in 1854 and 1855 (see Appendix iv., p. 589); and in 1861, after his official connection with the Island was severed, he wrote an excellent guide-book for a London publisher,³ which contains his latest summary of Manx geology.

Cumming seems to have been the first writer to apply modern stratigraphical terms to the rocks which we now call the Manx Slates. These in his first book he referred, with some hesitation, to the Lower Silurian as then understood, while in his latest work he defined them as "rocks which it may be convenient at present to include under the general term Cambro-Silurian, intending thereby all the rocks under the Upper Silurian of Sir Roderick I. Murchison."⁴ The Peel Sandstone and the Conglomerate resting unconformably on the slates at Langness he classified as Old Red Sandstone, but noted that at the latter locality the conglomerate "passes by a regular gradation into, and appears as a lower member of, the Carboniferous

¹ "On the Geology of the Isle of Man. Pt. I. The Palæozoic Rocks of the Island."—*Quart. Journ. Geol. Soc.*, vol. ii., pp. 317-335. "Part II. The Tertiary Formations."—*Ibid.*, pp. 335-348. "On the Geology of the Calf of Man."—*Ibid.*, vol. iii., p. 179.

² "The Isle of Man; Its History, Physical, Ecclesiastical, Civil and Legendary." 8vo. London. 1848.

³ "A Guide to the Isle of Man," etc., etc. Stanford, London. 1861.

⁴ Stanford's Guide, ed. 1861, p. 158.
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Series,"¹ and he considered that the same conditions would be found at Peel if the higher strata had been preserved. The Carboniferous Limestone Series he divided into Lower Carboniferous Limestone or Castletown Limestone; Upper Carboniferous Limestone or Poolvash Limestone, belonging to the Yoredale Series; and Posidonia Schist or Poolvash Black Marble, with the upper part of which he associated the Contemporaneous Volcanic Rocks of Scarlet. These divisions he substantiated by palæontological lists, based on his extensive collection of the fossils,² and so far as this branch of the subject is concerned there has not since been much advancement made upon his results.

In respect to the Drift deposits, his statement of their leading characters was full and particular, and he recognised, apparently for the first time, their Glacial origin.³ Though attributing more to the action of floating ice than would now be generally acknowledged, his theoretical conclusions in these matters were in advance of most of his contemporaries and of some of his successors. Thus he remarked (*op. cit.*, p. 341): "There appears no necessity for supposing any extraordinary rush of water or more powerful waves or currents than there are at present, but simply a difference of climate." He paid especial attention to the distribution of the boulders of the Foxdale Granite on South Barrule at higher levels than their source, being at first inclined to consider their transportation as evidence for "the agency of some great cataclysm,"⁴ but finally accepting the explanation offered by Charles Darwin,⁵ with whom he had been in communication on the subject, that they were lifted by the action of shore-ice on a sinking land.⁶

In Cumming the study of Manx geology on modern lines had an adequate commencement, but for many years afterwards made very little further progress. A few Manx Carboniferous fossils were described in the monographs of McCoy, Milne-Edwards and Haime, Davidson and others (see Appendix, pp. 589-91); some general sketches based on, and inferior to, Cumming's, were published in scattered guide-books and periodicals; and between 1862 and 1865 there was some discussion of certain markings in the Slates, supposed to be fossil foot-prints, but in reality the hollows left by decayed nodules (see p. 92). About this time the geology of the Island began to attract the attention of Lancashire geologists who spent vacations there, and published occasional papers on the subject in the Transactions of the scientific societies of Manchester and Liverpool. The earliest of these seems to have been a communication in 1864 to the Manchester Geological Society on the Slate Series,⁷ by

¹ Stanford's Guide, ed 1861, p. 160.

² This collection is still contained in the Library of King William's College, Castletown, but unfortunately is now in poor condition (*see p.* 251).

³ Quart. Journ. Geol. Soc. vol. ii. (1846), p. 340.

⁴ "Isle of Man," p. 178.

⁵ Quart. Journ. Geol. Soc., vol. iv., pp. 315-323.

⁶ Stanford's Guide, p. 168.

⁷ "The Cambrian Strata of the Isle of Man," by J. [E.] Taylor.—Trans. Manchester Geol. Soc., vol. iv., pp. 70-107.

J. [E.] Taylor, who claimed that these rocks were probably of Cambrian age.

In 1866 the Slate-rocks were investigated by Harkness and Nicholson,¹ who correlated them, on somewhat unsatisfactory grounds, with the Skiddaw Slates of the Lake District; and henceforward it has been customary to apply this appellation to the Manx Slates (see p. 115).

The next addition to the literature requiring our attention is a paper by Mr. J. Horne, published in 1874,² in which the Peel Sandstone and Langness Conglomerate were compared with the Calcareous Sandstone Series of Scotland, the Volcanic rocks of Scarlet and Poolvash were carefully described, and the Glacial Drifts were for the first time discussed on the land-ice hypothesis.

The renewed interest in Glacial subjects excited about this time by the works of J. Croll and James Geikie was also reflected in speculative papers on the Manx phenomena by J. A. Birds and (Sir) H. H. Howorth, and in a discussion arising therefrom in which J. Horne, G. H. Morton, and A. Strahan participated (see Appendix, p. 590).

In 1877 E. W. Binney described and figured certain obscure worm-markings from the Manx Slates.³ Some valuable observations on the same rocks were published in 1880 by the Rev. J. Clifton Ward,⁴ who visited the Island for the purpose of comparing them with the Skiddaw Slates of the Lake District which he had recently surveyed. His examination disproved the supposition of Harkness and Nicholson that the Borrowdale Volcanic Ashes were represented among the flags of the eastern coast-line, but was on the whole favourable to the general correlation of the Manx Series with the Skiddaw Slates. In the same paper he gave an instructive account of the Carboniferous Volcanic Series, in which he recognised the effects of submarine volcanic action; and concluded with a general summary of the Drift phenomena.

A useful list of Manx Minerals by Sir Warrington W. Smyth was issued by the Isle of Man Natural History and Antiquarian Society in 1888.

In the same year there appeared the first of a series of contributions to the literature by Prof. W. Boyd Dawkins.⁵ In

¹ "On the Lower Silurian Rocks of the Isle of Man," by Prof. R. Harkness and H. A. Nicholson.—*Quart. Journ. Geol. Soc.*, vol. xxii., p. 480.

² "A Sketch of the Geology of the Isle of Man," by J. Horne, of the Geological Survey of Scotland.—*Trans. Edinburgh Geol. Soc.*, vol. ii., pt. iii. (1874), pp. 323-347.

³ "A Notice of Some Organic Remains from the Schists of the Isle of Man," by E. W. Binney.—*Proc. Lit. and Phil. Soc.*, Manchester, vol. xvi., p. 8.

⁴ "Notes on the Geology of the Isle of Man," by J. Clifton Ward.—*Geol. Mag.* (1880), dec. ii., vol. vii., pp. 1-9.

⁵ "On the clay-slates and phyllites of the South of the Isle of Man and a section of the Foxdale Mine," by Prof. W. Boyd Dawkins.—*Trans. Manchester Geol. Soc.*, vol. xx. p. 53.

this paper stress was laid upon the mineral alteration and mechanical deformation which the slates had undergone; and the quartzites interbedded with them were recognised as the source of the pebbles in the Langness Conglomerate. A second paper of the series, published in the following year, gave the result of the detailed investigation of these Carboniferous Conglomerates.¹

At this date commenced the periodical issue of the Journal of the Isle of Man Natural History and Antiquarian Society,² in the pages of which, during ensuing years, many original geological observations concerning the area have been recorded (see Appendix iv., pp. 591-595). The Manx Geological Society, established in 1888, though not issuing regular Proceedings has also from time to time added items of interest through the medium of the local newspapers.

In 1889 Messrs. Dickson and Holland published chemical analyses of some Manx igneous rocks (see Appendix ii., p. 575).

In 1891 Mr. B. Hobson, in furtherance of the investigations of Prof. Boyd Dawkins, contributed an important paper on the Carboniferous Volcanic and other igneous rocks of the south of the Island, in which for the first time the resources of modern petrography were brought to bear upon the subject.³

Mr. H. Bolton who at the suggestion of Prof. Boyd Dawkins had made a careful search for fossils in the Slate-rocks, recorded⁴ in 1893 the finding of the cast of a trilobite in these strata near Ramsey, and afterwards added the further discovery of *Dictyonema* in an old quarry near Sulby.⁵ More recently Mr. Bolton has dealt with the palaeontology of the Slates as a whole,⁶ and has brought together all the existing information on this difficult subject. A considerable portion of this paper has been reprinted on later pages of the present work (pp. 90-94).

The most noteworthy contribution to the Glacial literature of the Island since that of Cumming was made by Mr. P. F. Kendall in the pages of Yn Lioar Manninagh in 1894,⁷ a brief outline of

¹ "On the Geology of the Isle of Man. Pt. I. On the Conglomerates of the south of the Island." Vannin Lioar (Journ. I. of Man Nat. Hist. and Antiq. Soc., vol. i., pt. i., p. 16).

² Under the title of Vannin Lioar, afterwards altered to Yn Lioar Manninagh.

³ "On the Igneous Rocks of the South of the Isle of Man," by B. Hobson.—Quart. Journ. Geol. Soc., vol. xlvii., p. 432-450 (Reprinted, with additions and corrections, in Yn Lioar Manninagh, vol. i., no. 10, pp. 337-348, April, 1892.)

⁴ "On a Trilobite from the Skiddaw Slate of the Isle of Man," by H. Bolton.—Geol. Mag., dec. iii., vol. x. (1893), p. 29.

⁵ "Observations on the Skiddaw Slates of the North of the Isle of Man," by H. Bolton.—Rep. British Assoc., Nottingham, 1893, p. 770.

⁶ "The Palaeontology of the Manx Slates."—Manchester Memoirs, vol. xliii. (pp. 1-15, pl. i.).

⁷ "On the Glacial Geology of the Isle of Man," by P. F. Kendall.—Yn Lioar Manninagh, vol. i. pt. 12 (1894), p. 397.

the author's results having been previously given before the British Association in 1890, and again in Wright's "Man and the Glacial Period" in 1892. Mr. Kendall made an exhaustive study of the palæontology of the drifts, and the conclusions stated in the final page of his paper were that in spite of the presence of marine shells in places, marine action played no part in the history of the Isle of Man during the Glacial Period, and that "the glaciation was effected by moving land-ice which overtopped its highest mountain." These results the work of the Survey has confirmed.

Discoveries of great consequence, not only to Manx Geology but to that of the whole of the northern part of the Irish Sea basin, were the outcome of deep borings in search of coal at the northern extremity of the Island begun in 1891 by Messrs. Craine Bros. of Liverpool.

The possibility of the extension of the Whitehaven Coalfield beneath the sea to this part of the Island had long before been discussed by Cumming and other writers (*see* p. 280); and a systematic attempt was now commenced to decide this question. At the time of writing this work is still in progress, and though the main object of the enterprise has not been attained, the presence of Triassic (including Saliferous Marls), Permian, and Lower Carboniferous strata has been demonstrated, the rock-floor being reached beneath the drifts at depths varying from 160 to about 400 feet below sea-level.

The results obtained from the three earlier of these borings were made public by Prof. W. Boyd Dawkins in 1894² and 1895,³ and the details of a fourth were given by Mr. John Todd, the resident engineer, in a paper published in 1896⁴. An account of these and two later borings will be found in Chapter VII. of the present volume.

In the first of the above-mentioned papers Prof. Dawkins furthermore discussed the Peel Sandstones, attempting to show that instead of being either Upper Devonian or Lower Carboniferous as usually hitherto held, they were of Permian age. This view was again stated by the same author in a short general sketch of Manx geology published in 1896.⁵

In 1895 some curious effects of earth-movement upon the Slate Series, by which large tracts have been reduced to the

¹ International Scientific Series.

² "On the Geology of the Isle of Man. Pt. I. The Permian, Carboniferous, and Triassic Rocks, and the New Saltfield of the North," by Prof. W. Boyd Dawkins.—*Trans. Manchester Geol. Soc.*, vol. xxii., pt. xxi., p. 590.

³ "On the Geology of the Isle of Man. Part II. by Prof. W. Boyd Dawkins.—*Trans. Manchester Geol. Soc.*, vol. xxiii., part vi. p. 147.

⁴ "On the Borings for Coal, and the Experimental Salt Works in the North of the Isle of Man," by John Todd.—*Yn Lloar Manninagh*, vol. iii., pt. ii., p. 65-72.

⁵ "On the Geology of the Isle of Man," by Prof. W. Boyd Dawkins — *Rep. British Assoc. Liverpool*, 1896, pp. 776-779.

condition of "Crush-conglomerate," were described by the present writer and Mr. (Prof.) W. W. Watts.¹ In the following year a brief "Outline of Manx Geology" was contributed by the writer to the Handbook for the Liverpool Meeting of the British Association.

At the above-mentioned meeting a monetary grant was made to enable a Committee, with local assistance, "to examine the conditions under which remains of the Irish Elk are found in the Isle of Man," and excavations were undertaken under the superintendence of Mr. P. M. C. Kermode, which have yielded instructive evidence as to the succession of animal and plant life since the Glacial Period (*see* p. 384). The discovery of an almost perfect skeleton of the Elk in one of these excavations has been described by Mr. Kermode.²

In his "Ancient Volcanoes of Great Britain"³ published in 1897, Sir A. Geikie, at that time Director-General of the Survey, gave the result of his examination of the Carboniferous Volcanic Series of Scarlet. This account contains much new information respecting these rocks and their correlation with the analogous formations of the mainland.

The "Annual Reports" of the Director-General for the years between 1892 and 1897 give the outlines of the more prominent results of the official Survey. A short paper on "Some effects of Earth-movement on the Carboniferous Volcanic rocks of the Isle of Man" was also communicated to the Geological Society in 1899 by the present writer.⁴

¹ The Crush-Conglomerates of the Isle of Man," by G. W. Lamplugh and W. W. Watts.—Quart. Journ. Geol. Soc., vol. xli. (1895), pp. 563-597.

² "The Irish Elk, *Cervus giganteus*, in the Isle of Man," by P. M. C. Kermode.—Geol. Mag., dec. iv., vol. v. (1898), pp. 116-119; also in other Reports, etc., for which see Appendix, pp. 594-5.

³ London, Macmillan & Co., 2 vols. (8vo.).

⁴ Quart. Journ. Geol. Soc., vol. lvi. (1900), pp. 11-25.

PART II.—THE STRATIGRAPHY OF THE ISLAND.

CHAPTER III.

THE MANX SLATE SERIES.

HISTORICAL AND INTRODUCTORY.

The position of the Manx Slates in the stratigraphy of the Island and their relationship to its physical features have been outlined in a previous chapter, and need little further comment. At some period probably about midway in Palæozoic times, this great series of slaty, gritty and flaggy strata was ridged up by powerful crustal movements in complex fashion along an axis ranging north-east and south-west, and thus remains as the central framework of the Island.

Before the commencement of the Carboniferous period, erosive influences had cut deeply into this old massif, the rocks of which at that time already possessed the lithological and structural characters that we find in them to-day. By this early denudation there seems to have been shaped out an isolated hilly tract approximately resembling the present land, which was probably afterwards buried under sediments of Carboniferous and later times, and thus during long ages protected from erosion. By the stripping away of these enfolding strata, probably finally accomplished during Tertiary times, the central portion of the old ridge was once more exposed, and must since have lost considerably in altitude.

The older geologists, Berger, Macculloch and Henslow, in describing the Island, were content to classify the slate-rocks according to their lithological characters as mica-schists, clay-schists, slates, greywackes, etc., without attempting further to distinguish them. Cumming, writing in 1848, seems to have been the first to attempt a closer definition. He remarks:—"of the geological age of the schists we have no good criterion, the few undetermined fucoids and corallines in the newer portion being insufficient guides; they are probably, as far as developed, Lower Silurian."¹ His later opinion that they were "Cambro-Silurian" has already been quoted (p. 19); as also Mr. Taylor's contention in 1864 that they were probably Cambrian (p. 20).

The first definite correlation of the rocks with the Skiddaw Slates of the Lake District appears to have been made by Harkness and Nicholson in a brief paper in 1866,² though these authors wrote as if the probability of this relationship had

¹ "Isle of Man," p. 238.

² Quart. Journ. Geol. Soc., vol. xxii., p. 488.

been already recognised. They supported the correlation by the mineral characters of the strata ; by the presence of *Palæochorda major*, "a fossil very abundant in the Skiddaw Slates of Cumberland"; and by the correspondence in strike—"the Lower Silurian rocks of this Island being on the exact line of strike of the Skiddaw Slates of the Skiddaw country and of their overlying green rocks." They stated, moreover, that "green slates and porphyries" occurred on the eastern side of the Island which were "equivalents of the ash-beds and porphyries which succeed the Skiddaw Slates of the Lake-country," though somewhat different "in being more quartzose and in having the ashy rocks better bedded."

This statement as to the presence of Volcanic rocks in the east of the Island comparable to the Borrowdale Volcanic Series was shown, however, by the Rev. J. Clifton Ward in 1880¹ to be erroneous, since sandy and gritty beds only were contained in the sections indicated.² The same author, whose intimate knowledge of the Skiddaw rocks of the Lake District gave especial value to his opinion, summed up his investigation of the Manx Series as follows—"The rock occurs in four forms. 1. As a coarse thick-bedded sandstone or grit, slightly conglomeratic in parts. 2. As more or less thickly-bedded flags of a grey colour within but often irony on the outside. 3. As black slate frequently flaggy in character and occasionally cleaved. 4. As soft black shale, not unlike coal-measure shales. All these forms also recur in the Lake District Skiddaw Slate Group. . . . It would be unsafe to offer any decided opinion upon the divisions of the Skiddaw Slate in the Island without having made a detailed survey of the whole, and still more so to point to certain parts as the equivalents of Lake District divisions." He also remarks that "on the east side of the Island especially, the beds appear much more sandy than is the general character of the series in the Lake District."

Mr. J. Horne, in commenting on the supposed Skiddaw age of the series, remarks— "[If this correlation be correct,] . . . they are inferior in position to the Silurian rocks of the south of Scotland. Lithologically, they are totally different from any part of that series."³

No further evidence in support of the correlation has been forthcoming, and the reasons adduced in the above extracts are not convincing. Nevertheless it has become the established custom to apply the designation of "Skiddaw Slates" to the Manx rocks, apparently as much from lack of an alternative term as from any other cause. Certainly none of the arguments on which Harkness and Nicholson based the correlation will stand a critical examination. The supposed existence of rocks resemb-

¹ Geol. Mag. dec. ii., vol. vii., p. 2.

² The existence of "thick sheets of Volcanic Ash" in the series was again stated by Mr. H. Bolton in 1893 (Report British Assoc., Nottingham, 1893, p. 770) but was based on a similar misconception.

³ Trans. Edinburgh Geol. Soc., vol. ii., part iii. (1874), p. 5.

ling the Borrowdale Volcanic Series has been disproved. The palæontological argument, based entirely on the occurrence of Palæochorda, a worm track, already of the weakest, is rendered nugatory by the absence, so far as is known, of any of the Skiddaw graptolites, trilobites, or other fossils. The lithological comparison has somewhat greater strength, but as Clifton Ward has shown, it can only be applied in a broad general way and cannot be followed out in detail. In fact the same comparison might be made with any of the monotonous masses of slate and greywacke which occur so commonly in the British Islands among the Older Palæozoic strata. As for the north-east to south-west strike, this is not a feature peculiar to the Skiddaw Slates, but is common to that wide region surrounding the northern part of the Irish Sea, wherein the Lower Palæozoic rocks were thrown into folds by the great Mid-Palæozoic system of earth-movements; and moreover the detailed mapping of the Manx strata has shown that their true line of strike is directed somewhat to the northward of the Skiddaw Slate outcrops in Cumberland, and that it is only in regard to the strike of the cleavage-structures the two areas are linked.

It has also recently been shown¹ that, as long suspected, the rocks known collectively as the "Skiddaw Slates" in the Lake District itself, include deposits ranging in time from the Lower Silurian to an unknown downward limit in the Cambrian, and that the term though useful as an expression of local stratigraphy has no value as a systematic division.

Under these considerations it seems very undesirable that the ill-defined title should be extended beyond its original local application. Hence we propose to cease using the term for the Manx rocks, and to substitute for it the expression "Manx Slate Series" or "Manx Slates." This course has been adopted on the map which has been issued by the Survey.

After having mapped a considerable area of these rocks in the Isle of Man, the writer spent a few days in the spring of 1895 in examining the Skiddaw Slates of the mainland in the neighbourhood of Keswick for the purpose of comparing the rocks of the two areas. Failing to obtain any definite results, he made in the following year a similar examination of the Black Combe district; and has since visited, for the same purpose, some outcrops in the Cleator district of Cumberland, but still without finding any convincing evidence for the correlation. Along with a certain general similarity in lithological character, one notices many points of difference, which while quite possibly explicable as lateral changes of the original sediments in different parts of the same basin of deposition, or even as partly due to unequal subsequent dynamic or other alteration in these distinct areas, are yet sufficient to destroy confidence in the correlation. Thus, besides the apparent absence from the Manx Slates of the characteristic fossils of the Skid-

¹ "The Skiddaw Slates," by J. E. Marr, *Geol. Mag.*, dec. iv., vol. i. 1894), p. 122.

daw Slates of the Lake District, the greywackes and grits of the Island have usually a different composition and aspect from those of the mainland; and the argillaceous members are much more sericitic, and rarely, if ever, possess the dull muddy character of most of the fossiliferous outcrops of the Skiddaw Slates proper. In both areas the strata have undergone great deformation, but the shearing of the Manx rocks has been exceptionally severe, and the resultant structures are much more strongly marked in them. On the other hand, the Lake District rocks exhibit much greater contact-alteration in the vicinity of igneous intrusions than the Manx rocks, though this of course does not affect the question at issue.

But in spite of this lack of proof, it is nevertheless probable that the actual time-equivalent of some part, at least, of the Manx Slate Series has its place among the lowermost portion of the Skiddaw Slates. This matter will be further discussed on a later page (p. 115).

During the progress of the survey of the Island brief accounts of the steps taken in dividing the Manx Slates were published in the Annual Reports of the Director-General of the Survey for the years 1894-5-6, and in the paper on "Crush Conglomerate" (see p. 55), by W. W. Watts and the writer. The terms adopted for the subdivisions of the Slates on the Geological Map and in the present volume, were first mentioned in the above paper and in the Report for 1895, p. 5.

The contributions of Mr. Bolton to the Palæontology of the series are discussed under a separate heading (see p. 89).

GENERAL DESCRIPTION OF THE MANX SLATES.

The distinct lithological types comprised in the series may be traced with more or less certainty throughout the Island, but the difficulties in defining their limits and order of superposition have been found almost insuperable. Their meagre palæontology affords no assistance, so that our only guidance is in the mineral characters of the strata, which unfortunately, besides an original lack of sharpness of definition, have been so greatly complicated by structural changes that it is often impossible to follow them in detail. A much more prolonged investigation than it was found practicable for the present writer to undertake would have been requisite to unravel the effects of unequal and changeable deposition; of folding, crushing and overthrusting; and of subsequent displacements, upon these ancient sediments, so that it cannot be pretended that more has been done than to trace out the broader elements of their stratigraphy.

There is every reason to believe that the different lithological types of which the series is composed have been deposited as a conformable sequence, passing into each other without break. This passage, indeed, in certain areas seems to take place laterally as well as vertically, the rocks of an arenaceous type in one area apparently becoming more argillaceous in another. The whole

series thus forms a stratigraphical unit, the base of which is nowhere revealed, while the uppermost portion has been removed by Pre-Carboniferous denudation.

That these sediments were of marine origin there can be no doubt; and from their extent and diversity we may conclude that they were deposited on a subsiding area in a sea of moderate depth at no great distance from land. Since they contain nothing which we can recognise as beach-material, it would appear that the shore-lines of this sea lay always beyond the area. From the character of the grit-fragments in the coarser sediment (see pp. 98-9), some slight evidence may be gleaned as to the composition of the land which was being wasted to supply the material for these rocks; it appears to have comprised older sedimentary strata, both argillaceous and arenaceous, as well as volcanic and massive igneous rocks.

As is usual among the Older Palæozoic rocks of the British Isles, the Manx Slates are characterised by a paucity in calcareous constituents. A small percentage of lime (see pp. 34-6) is occasionally present in the finer-grained flags or mudstones, either disseminated through the mass or concentrated into slightly calcareous nodules; but usually this material is entirely wanting, except for such as is contained in the decomposed basic igneous dykes by which the Slates are traversed.

The slaty and gritty sediments occur both separately and in every stage of admixture. At the one extreme we find dark blue or blackish clay-slate, often altered into phyllite; and at the other, almost pure quartz-grit or quartzite arranged in flaggy bands, with thin argillaceous partings. Between these extremes lies every gradation of sandy slate, mudstone, greywacke and impure grit or flag. The extreme types occur in fairly well-defined belts, but between them are broad tracts in which, either from original variable sedimentation or from the intricacy of the folding and crushing, the different varieties are so closely intermingled as to be practically inseparable. Of course under such conditions the mapping of the boundaries of the divisions must necessarily be more or less approximate and diagrammatic; and the minor features can hardly be deciphered. Indeed, so great has been the displacement and distortion of the rock-masses that, while the main divisions have been traced out, their relative order has not been established with any certainty, and still remains a matter of inference. The chief impediment to more detailed stratigraphical work has been the failure to find bands smaller than these main divisions, with characters distinct enough to be constantly recognisable. On the discovery of such bands any future advance in our knowledge of the district will probably depend, and it should therefore be made the prime object of the next investigator. In different parts of the Island, bands were noticed which at first seemed to promise well for the purpose, but none proved traceable for more than a short distance. These instances will be duly noted in the 'detailed descriptions' of the succeeding chapter; and it may be that among them the requisite more definite clue to the structure of the area will eventually be found.

In mapping the series, the scheme which was adopted as best suited to the circumstances has been to separate out the wider belts of similar lithological composition into divisions to which a nomenclature has been attached, but not to attempt to divide those tracts in which the rocks are ill-defined in character, or in which the different types are closely intermingled. It is indeed highly probable that in some places the "unseparated" rocks may be equivalent to portions of "separated" divisions of other localities; but the former will generally be found to consist either of strata of passage-type which do not fall conveniently into any class, or of rocks in which the original structure has been greatly altered and obscured.

The subdivisions are shown on the map as follows:—

Manx Slate Series.	$\left\{ \begin{array}{l} a''' \text{ Barrule Slates.} \\ \quad \text{"Crush Conglomerate."} \\ a'' \text{ Agneash and other Grits.} \\ a' \text{ Lonan Flags and Niarbyl Flags.} \end{array} \right\}$ Cambrian ?
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The order in which they are written is supposed to be their true downward sequence, for reasons now to be briefly stated, and to be more adequately discussed after the field-evidence has been presented. It must be understood that this supposed succession of the strata is not in accordance with the views hitherto held as to the structure of the Island. By Cumming, Ward and most, if not all, the later observers, the anticlinal axis running north-east and south-west through the interior of the Island, from which the dominant structural planes of the strata dip away on both sides almost throughout the massif, has been supposed to indicate the true arrangement of the Slate Series; and under this supposition the oldest rocks would lie in the vicinity of the axis, with the newer strata dipping away successively on both sides. Hence the rocks on the outer flanks of the Island would be the newest, instead of, as now suggested, the oldest portion of the Series. My¹ investigation has shown, however, that the axis is primarily an anticline of the cleavage-structures and not of the bedding, and that the apparent dips are altogether misleading as to the superposition and stratigraphical relations of the strata; and I have concluded from the whole of the field evidence that, instead of forming a stratigraphical anticline, the rocks are probably arranged in a compound syncline or *synclinorium*, made up of closely packed folds, of varying amplitude, which expand outward from the centre. To such conditions the term "compound fan-structure" has sometimes been applied. In this case the oldest and not the newest beds would occur on the outer flanks of the massif, as illustrated in the diagram, Fig. 32, p. 118.

¹ Throughout this volume the pronoun in the *first person singular* is confined as far as possible to passages discussing hypothetical matters in which the personal factor may have had much influence upon the interpretation. Its use therefore denotes that the statements rest largely upon a basis of personal judgment.

If this view of the structure be accepted, we must consider the arenaceous flags, which on both sides of the Island occupy the ground adjoining the coast and extend inland toward the central ridge, as older than the grits and slates of the interior which they apparently overlie. Hence in our description of the strata in ascending sequence, we shall commence with these flags.

The flags of the western coast are probably the equivalents of the rocks which resemble them on the eastern margin of the Island; but as their outcrops are separated by nearly the whole breadth of the Island, and as they do not possess characters so definite as to place their identity beyond doubt, it has been considered advisable to describe them separately under distinctive local names. To the flags of the eastern coast, the designation of "Lonan Flags" has been applied, from their wide development in the parish of that name; while for those of the western side, the term "Niarbyl¹ Flags" has been selected, from The Niarbyl, a prominent reef jutting out from the coast at Dalby, in which these flags are typically developed.

The Lonan Flags.

On the eastern coast, from Maughold Head in the north to the margin of the Carboniferous basin in the south, the cliff-sections reveal a predominance of flaggy mudstones and fine-grained grits, usually of bluish-grey or greenish tint, with darker more argillaceous intercalations. In their local modifications, these rocks vary between the extremes of almost pure quartz-grit on the one hand and almost pure clay-slate on the other; but they are characterised throughout by their colour-banding and flaggy stratification, by which the bedding planes are rendered distinguishable even where the superinduced fissile structures are predominant. The old designations, 'greywacke' and 'slaty greywacke,' are perhaps still the best descriptive terms to apply to these rocks. The thinly bedded slaty portion of the series might in some places be separable from the more thickly bedded sandy rocks, but they are so intimately related that the task would be full of difficulty. Certain beds of coarsish grit which appear to form part of the series in the vicinity of St. Ann's (Santon) Head, and again between Douglas and Clay Head seem however to mark definite horizons, and these have been indicated on the one-inch map.

The prevalent dips of the Lonan Flags are high, ranging usually from 45° to vertical, the direction being generally from the central axis towards S.E. or S.S.E., except in a narrow belt running from Clay Head to Douglas Head, where they are in the opposite direction. Evidences of severe deformation are almost everywhere visible in the deeper sections, and even where not immediately perceptible, closer examination will usually

¹ Pronounce Né-är-bl.

reveal the sharp crests and troughs of folds partially masked by strain-slip planes. In the exceptional cases where the angle of bedding is apparently low, the presence of an overturned recumbent fold may always be suspected; and may indeed sometimes be demonstrated, as in Fig. 2.

The angle of dip frequently brings the bedding into approximate coincidence with the strain-slip cleavage planes, the strata then often assuming a deceptive appearance of undisturbed regularity; so that in the deeper cliff-sections, as in the vicinity of Bulgham Bay, a sequence of beds many hundreds of feet thick seems to be presented. But the detailed investigation of these sections generally reveals indications of repetition, either by folding or by thrust-faults, and it is doubtful whether the

FIG. 2. *Cliff-section 700 yards S.S.E. of Maughold Head, showing recumbent fold in striped slates with thin grit bands. Height, about 15 feet.*



A faint cleavage parallel to the stratification in the limbs of the fold crosses the beds in the upfold, diverging somewhat in the gritty bands.

natural sequence has been anywhere preserved in more than a comparatively small portion of the mass. No safe estimate of the thickness of the Flags can be based on these sections.

The superinduced structures which the strata ordinarily present are those which usually accompany acute folding. They suggest an intimate fluxion or sliding of the particles throughout the mass of the rock, more or less parallel to and determined by the planes of bedding. These movements have given rise to 'flaser'-structure and strain-slip-cleavage which is often beautifully revealed when thin sections of the rock are examined microscopically, and to various peculiar modifications of the bedding on a larger scale, hereafter to be described (pp. 73-83.)

Hence it is probable that the Lonan Flags throughout their

range constitute a series of closely-packed isoclinal folds. The further inference that they form the lowermost division of the Slates has previously been stated. They seem, for the most part, to have been folded upon themselves, into an irregular platform. The overlying strata were somewhat differently affected by the movement, so that the infolding of the upper series with the lower has been comparatively slight, and confined to rather narrow vertical limits near the junction of the masses. There is scarcely any safe basis on which to build an estimate, but the original thickness of these flags was probably great. At Laxey the shafts of the mines, situated in a valley which has been excavated in these flags to a depth of 700 feet or more, descend a further 1,800 feet into them without reaching their base or revealing any marked change, their dip throughout being steadily in one direction at angles of from 40° to 70° . Horizontally their outcrop frequently extends for over two miles, measured at right angles to their strike, with the dips persistently high. These facts seem to postulate a great original thickness for the division, and its wide lithological variability is also favourable to this supposition.

From the acute character of the folding as revealed in the cliff-sections, it is inconceivable that any individual fold in these rocks can have a depth from crest to trough at all commensurable with the proved depth of the whole division. It is therefore tolerably certain that the plications, even within the mass of the flags, have taken place to some extent independently at several different horizons, and that the thickness of rock crumpled up in any individual fold is not large. This arrangement of folds in superimposed belts must, of course, tend to pile up the strata to an almost indefinitely exaggerated extent vertically as compared with their original thickness. The same structure appears to pervade, in variable degree, all parts of the Manx Slates. It could only occur in a region of intense compression, and thus affords support to my view that these rocks occupy part of a synclinorium. As to the maximum amplitude which the individual folds may attain we have scarcely sufficient evidence, but to judge from the length of unbroken dip-slope in some of the cliff-sections, the limbs of the folds may occasionally extend for some hundreds of feet, though usually they are shorter. Regarding this point, it is noteworthy that among the Lonan Flags the folds are generally straighter-limbed and more regularly isoclinal than in other parts of the Island, probably from the more frequent coincidence of the planes of bedding with those of strain-slip movement.

Besides the effect of the folding, there are indications that at a later date these rocks have been displaced in blocks, by faults of various kinds, both normal and reversed; but it is exceedingly difficult, from the general obscurity of the ground, to trace the course of these faults or to recognise the extent of the displacement; and under these circumstances it has not been thought desirable to obscure the map by attempt-

ing to show them. They will be separately discussed on a later page (see p. 86).

From the coast-sections in which they are typically developed we may trace the Lonan Flags inland, in the northern portion of the massif, up to the belt of Agneash Grits, into which they appear to merge gradually with every indication of a conformable passage. In the area south of the central valley of the Island, where the Agneash Grits seem to be wanting, the inland margin of the division becomes doubtful, the flaggy character being gradually lost amid the banded slates with occasional gritty intercalations which occupy the interior to the northward and north-westward of the Carboniferous basin. It is not improbable that these banded slates may represent a tract of the more argillaceous type of Lonan Flags in which the distinguishing characters have been modified by some different effect of earth-movement in the vicinity of the structural axis, since the presence in other areas of masses of 'crush-conglomerate,' produced by the smashing up of similar flaggy strata by these forces, is sufficient to prove how profoundly the aspect of such rocks may be altered. But as no method has been devised for proving the identity of the Flags where their recognizable characteristics are absent, it has been considered advisable to restrict the division to the area of its typical development, leaving an indefinite boundary where it merges into the 'banded slates.' The latter rocks constitute the chief portion of the 'unseparated' tracts of the map.

The greenish arenaceous strata of Clay Head and Douglas Head, which, with the numerous greenstone dykes traversing them, were mistaken by Harkness and Nicholson for Volcanic Ashes, form part of the Lonan Flags. Rocks of similar character are exposed on other parts of the eastern coast, as for instance between Port Mooar and Port Cornah, and between Laxey and Garwick.

The "worm-tracts" and other obscure markings of like character, which are almost the only organic relics of the Manx Slates, are more plentiful in the Lonan Flags than in any other part of the series. They are best seen at the junction of sandy and slaty layers. Mr. Bolton has shown that they include at least two distinct types (see p. 91).

These Flags are further characterised by the occasional presence of irregular lines of slightly calcareous concretions. The nodules vary in size, the medium being about six inches in diameter. They are of lenticular shape, usually flattened and somewhat drawn out by shearing. They are commonest in the 'thicker bands of mudstone or fine grit, though not altogether absent from the more laminated argillaceous beds. The amount of lime which they contain is always small, and appears generally to be in the form of dolomite. Occasionally no trace of lime can be detected in them, and those in the more gritty rocks sometimes exhibit in their interior a curious concentration of sand-grains coarser

than the sandy matrix of the nodule. In the more argillaceous strata the nodules are frequently pyritous, and not unlike the ordinary clay-ironstone concretions of newer rocks, which they further resemble in sometimes possessing imperfect cone-in-cone structure in their outer crust. Careful search has been made in these nodules for organic remains, for which they seemed to offer promise; but none has been found, though they have been examined in thin sections under the microscope as well as in the field. The microscopic sections revealed, however, some interesting data in respect to the metamorphism of the rocks (p. 96).

These concretions often weather rustily, and at a more rapid rate than their matrix, hence giving rise to shallow depressions on the exposed surfaces of the flags, at more or less regular intervals. The futile discussion which arose from the mistaken supposition that these pittings might represent reptilian foot-prints has been mentioned on a previous page (p. 20).

Further details with regard to the local development of the Lonan Flags will be found in Chapter IV. (pp. 126-155); the curious structures developed in them by earth-movement are more fully discussed on pp. 73-86; and some data regarding their petrographical characters are recorded on pp. 96-99.

The Niarbyl Flags.

As already stated, the correlation of this division with the Lonan Flags, though hypothetical, rests on rather strong grounds. Whether the structure of the Manx Slates as a whole be a compound syncline as now suggested, or a simple anticline as previously supposed, a more or less symmetrical arrangement of the strata on the opposite sides of the central axis is implied; though as the axis, for the most part, lies nearer the western than the eastern coast of the Island there is less room for the development of the sequence in the former district than in the latter. Hence, the occurrence of this well-marked flaggy group on the western flank of the massif, agreeing fairly well in most respects with the Lonan Flags and with differences not greater than is usual in the lateral prolongation of rocks of this character, seems to afford a good basis for their correlation. This view is seriously weakened, however, by the apparent absence of the next group of the sequence, the Agneash Grits, which could not be definitely identified in this part of the Island; and there is likewise a difficulty in the relation of the Niarbyl Flags to the adjacent banded slates, which may however be due to overthrust faulting.

The Niarbyl Flags are brought in suddenly at Niarbyl Point, either by an overthrust or by a normal fault; and extend thence in a coastal strip for five miles northward to Peel, where they are cut out by the Post-Carboniferous

fault which brings in the Peel Sandstone. The average breadth of this strip is only about $\frac{1}{4}$ of a mile, but it has evidently been reduced by the encroachment of the sea, and may be merely the fringe of a broader tract now submerged.

These flags are, on the whole, finer in texture, more thickly bedded, and paler in colour than the Lonan Flags, and contain fewer of the dark argillaceous partings. Fine slaty mudstones predominate, usually of a pale bluish-grey colour, weathering brown and developing a smooth hummocky surface under wave-action. Some of the bands contain sufficient disseminated calcareous material to give a brisk effervescence with acid, and one of these on analysis was found to contain 4.4 per cent. of lime.¹

They present greater regularity of lithological type than the Lonan group; but this may be only because of their restricted extent, and it would perhaps be possible to find an equal area of the Lonan Flags which would exhibit corresponding uniformity. The only traces of organisms yet found in them are worm-casts like those of the other division. The strata in the Lonan Group which most nearly resemble the Niarbyl Flags are the rocks which occupy the cliffs between Port Mooar and Port Cornah.

The prevalent dips in the Niarbyl Flags are high, usually between 45° and 75° , in a direction slightly to the westward of north; but the rocks are everywhere buckled and folded, the cliff-sections revealing fine examples of these contortions. (Fig 3.)

The folding appears usually to be shallower and more complex than on the eastern coast, and the stresses which the rocks have undergone have been more intense. The strain-slip cleavage is more strongly developed than in the Lonan Flags, and more frequently traverses and blurs the bedding. The rock-structures due to the rucking up of the planes of stratification in one part of the fold, and their dragging out and planing off by stretching and shearing in another part, are beautifully developed in many places. Some curious examples of these structures are figured and described in the sequel (see pp. 73-86).

The inland boundary of the division is evidently the north-north-eastward prolongation of the overthrust, or fault of low hade, which as already mentioned is seen on the coast at The Niarbyl. Its direction is oblique to the apparent strike of the Flags, but is nearly parallel to the general orientation of the rock-masses of the Slate Series. It brings the flags up sharply against thinly-banded argillaceous rocks of ill-defined character, which are left as 'unseparated' on the map. The junction presents no signs of passage, and there is an absence of that looping together and alternation of the two rock-types along their margin which commonly mark the folded contact of the different divisions. In the coast-section, the slates

¹ I am indebted to Mr. Allan Dick, Junr., for this analysis.

FIG. 3.—Cliff-section in contorted Niarbyl Flags at Ballaquane Strand, near Dalby.
Height, about 20 feet.



Faint cleavage crossing the folds.

are seen to be greatly crushed and confused in the vicinity of the junction, and they appear to pass beneath the flags; and the same phenomena are probably continued inland along the line of contact, though the exposures in the interior are inadequate. Supposing the flags to be older than the slates, the apparent superposition of the former upon the latter must have been brought about by overthrust-faulting, and the junction above described would represent the thrust-plane. This supposition agrees with the general conditions in the Manx Slate Series, where it is common to find the harder and more massive strata breaking through the softer beds with which they come in contact, so that the thicker bands of grit and quartzite have often an intrusive dyke-like aspect, most extensive displacements of this kind being indicated by the 'crush-conglomerates' in the centre of the Island. Hence there is much likelihood that the Niarbyl Flags of the west coast represent a block of the lower strata which has been upfolded and driven forward over the beds which once covered them; and the apparent absence of strata which are requisite to complete the sequence in this quarter may be thereby explained.

In the vicinity of Peel, where the boundary is affected by the Post-Carboniferous faulting, the ground in the interior is heavily covered by glacial deposits, so that the exact limits of the flags cannot be defined. They form the ridge known as Peel Hill, but seem to give place to more slaty beds in the lower ground to the eastward, south of the River Neb. Where the Slates reappear in the coast-sections to the northward of the tract of Peel Sandstone, we find among them, in the neighbourhood of Ballanayre Strand, an outlying patch of thickly bedded flags resembling the Niarbyl Flags (too small to show on the one-inch map), bounded by faults and thrust planes, and on two sides in juxtaposition with masses of 'crush-conglomerate' made up of sheared fragments of similar flags set in a slaty matrix. (See pp. 67-69.)

Still farther northward there is a strip of flaggy grit, shown on the one-inch map, extending for three miles south-westward from Kirk Michael, which may possibly represent the northerly prolongation of the Niarbyl Flags. The stratigraphy of this district is, however, so complicated and uncertain that no confidence can be felt in the identification; and the strip has therefore been indicated on the map simply as a belt of grit, without correlation.

The Niarbyl Flags are traversed at intervals by igneous dykes of diverse age and composition (see pp. 146-9); but these intrusions are not nearly so abundant as on the opposite side of the Island.

Considerable interest attaches to a small patch of andesitic breccia which occurs close to the margin of the Niarbyl Flags at Ballnalargy, about half a mile south of Glen Meay, as it affords the only recognisable example of true volcanic material associated with the Manx Slates which has been found during

the course of the Survey. It is poorly exposed, and its relation to the surrounding rocks is obscure (see p. 163); but from the deformation which the material has undergone, its eruption if not actually contemporaneous with the deposition of the flags must have taken place prior to the great earth-movements which have affected them, and therefore at a period long prior to the Carboniferous period.

Fuller details in regard to the local development of the Niarbyl Flags will be found in the next chapter.

The Agneash Grits.

Scarcely any portion of the Manx Slates is wholly free from sandy intercalations. Even where their argillaceous character is most conspicuous, as in the Barrule Slates, it is occasionally broken by streaks of gritty material, while in the flaggy divisions the arenaceous element is always present and sometimes predominant. Hence it is evident that the basin of accumulation was receiving supplies of sandy material in a greater or less degree during every stage in the sedimentation of the series, and it is most probable that the deposition of sand in one part went on contemporaneously with the deposition of mud or clay in an adjacent tract. Under such circumstances the boundaries of the different sediments are not likely ever to have been sharply defined, and moreover their original limits have since been thrown into utter confusion by the folding and crushing together of the strata. The attempted demarcation of the chief masses of grit has therefore proved an extremely difficult task, especially where the flaggy grits of the divisions above described lay adjacent to the gritty flags now to be considered, or where thin-bedded grits gave place gradually to slates, through the thickening of the argillaceous partings with a correlative thinning of the sandy layers. The boundary lines of the grits, as shown on the map, are therefore necessarily to some extent arbitrary and diagrammatic.

With this warning as to the uncertain value of the boundaries adopted, we will commence with the study of the largest and most readily distinguishable of these grit masses, viz., that to which we have applied the term 'Agneash Grits.'

These grits are developed between Maughold Head and the central valley, along the north-western edge of the Lonan Flags, and might indeed be considered as a gritty phase of that division. The name adopted for them is taken from the Agneash Crag (Creg Agneash) overlooking the Laxey valley, in which they are typically exhibited. They consist of greyish splintery grits or imperfect quartzites, occurring in flaggy layers of a few inches to a foot or two in thickness, usually separated by thin argillaceous partings. The sandy component is mostly of fine texture, though occasionally there are bands in which the larger grains attain a diameter of 3 to 5 millimetres. A conspicuous characteristic of these rocks is the manner in which narrow strings

of vein-quartz, ranging up to about half an inch in thickness, traverse the grit-bands in every direction, filling an irregular system of crevices by which the grit-bands have been cut up into cubes of variable size and shape. Quartz-segregations are abundant in every division of the Manx Series, usually occurring in irregular reefs or gashes of more or less lenticular outline, or in long dyke-like veins; but this kind of criss-cross streaking of the rock with innumerable little strings of quartz is confined to the purer grits. The superior hardness of these beds has caused them to shatter during acute folding in places where the more plastic flags and slates amid which they lie have been squeezed and deformed with scarcely any actual rupture; and quartz has then gradually infiltrated the crevices, and re-cemented the bands.

This shattering and veining appears to be a common feature in regions where quartzites or highly indurated grits have been subjected to severe pressure and movement.¹ It is the first stage in the production of 'crush-conglomerate.'

The stresses which these grits have undergone are beautifully illustrated by the crumpled and buckled condition of the bedding wherever sections are revealed. Their complicated flexures are apparently the result of folding and refolding, and the simpler isoclinal type of plication found in the flags and banded slates is rarely displayed.

The strain-slip cleavages are far less evident in the grits than in the softer rocks adjacent to them, and are often only indicated by a slight tendency to fracture in a definite direction. Nevertheless the microscopic examination of the rock in thin slices usually demonstrates that dynamic action has affected every particle of it (see pp. 97-9).

The most northerly exposure of the Agneash Grits lies in the upper portion of the cliffs at Maughold Head between Traie Curn and Traie ny Foillan, where highly-plicated quartz-veined gritty flags with rather thick intercalations of more argillaceous material are revealed. The inland extension of these grits is hidden by the drift which fills the Port Mooar valley; and they are probably displaced by faults which range through this depression. About a mile to the westward, the rocky ground near Magher-e-breck exhibits an outcrop of much-disturbed grit, including, among flaggy beds, a massive band of coarser grain which was not recognised in the cliff-section. The same beds may be traced thence, at intervals, into the Cornah valley, where they are well displayed in the crags to the south-westward of the hamlet of Corran. From this place they extend westward along the steep valley-slopes nearly to the old Glencherry Lead Mine, and expand into a broad belt, broken by slaty and flaggy intercalations or infolds, on the moorland ridge to the southward. In climbing

¹ See "Some Dynamic Phenomena shown by the Baraboo Quartzite Ranges of Central Wisconsin," by C. R. Van Hise.—*Journ. of Geol. of Chicago*, vol. i. (1893), pp. 347-355.

southward out of the valley near the old mine we cross repeated outcrops of a massive coarse-grained grit-band like that seen near Magher-e-breck. These are almost certainly the repetition of a single bed by folding, though the steep and sometimes nearly vertical west-north-westerly dip gives the impression of a thick sequence of coarse-grained grits. The band seems to ascend the hill-slope in a succession of sharp shallow folds.

The grits range nearly to the summit of Slieau Ouyr, 1,483 feet above sea-level, and form the flanks of Slieau Lhean, 1,506 feet, an adjoining summit of the same ridge, but do not reach quite to its crest. Thence they are continued southwards into the bold Agneash Crag overlooking the Laxey valley. They probably extend into the bottom of this valley, but here as elsewhere when smoothed down in stream-beds by fluvatile erosion, they are not easy to distinguish from the Lonan Flags by which they are bounded. On the southern side of the valley they are readily recognisable in the rocky slopes of Cronk y Vaare, and, on the moorlands beyond, their outcrop expands to a width of nearly two miles, reaching from near Baljean on the east to the westward of the summits of Mullagh Ouyr and Carn Gerjoil (1,457 feet). In this space, however, the grits are interspersed with numerous belts of more argillaceous composition, probably representing infolds of the overlying strata, the field-evidence suggesting that an irregular zone made up of the folded grits approximates in this neighbourhood to the plane of the present surface of the moorland, and that this zone is almost cut through by the deeper valleys, and slightly overtopped by the higher hills. The same structure is suggested by the behaviour of the grits in other districts of the Island; but these zones of buckled grit appear themselves to have been thrown into folds, and further complicated by shear-planes and faults, so that they rarely extend far in the same plane.

Southward from Carn Gerjoil the quartz-veined grits continue to predominate on the gradually descending plateau lying to the eastward of the Baldwin valley, but with a contracting outcrop as the lower levels are reached, so that where they cross the valley at the junction of the Baldwin and Glass their width seems to be less than half a mile. They are well exposed on the southern ascent from this valley, but on reaching the crest they disappear beneath the drifts which cloak the gentler slopes descending to the Dhoo, and are no more seen in an identifiable form. If prolonged without change of strike into the central valley of the Island and to the southward beyond it, they would traverse comparatively low ground which is mostly cultivated and almost continuously drift-covered, wherein, therefore, rock exposures are infrequent and of small extent. So far as the evidence goes however, the rocks within this area are chiefly banded slates alternating with slaty flags, somewhat resembling the Lonan Flags, but not to be correlated with certainty with any division,

and therefore left 'unseparated' on the map. Gritty intercalations do occur here and there among these rocks (see p. 169), but seem always to be of very limited extent, and show no features by which they might be identified with the Agneash Grits.

These obscure conditions continue to the southward of the central valley for six or eight miles, after which, masses of quartz-veined grit and quartzite, comparable in appearance and stratigraphical position to the Agneash Grits, are again encountered, and may be followed thence, with some interruptions, to the south-western extremity of the Island. The correlation of these southern grits with the Agneash Grits, though highly probable, cannot be established with any certainty, in view of the possibility, already discussed, of the development of arenaceous rocks at different horizons in the series. The use of the same symbol and the same colour for separate grit-masses on the published map must not, therefore, be taken to imply that they have all been proved to occur at the same horizon. The indication of separate tracts in this manner has reference primarily to their lithological character, and not necessarily to their stratigraphical position.

The nearest equivalent of the Agneash Grits in position and general character in the south of the Island seems to be the strip which occurs at the northern margin of the Carboniferous basin, north of Ballasalla, in a ravine of Awin Ruy, the tributary of the Silverburn which flows southward from St. Marks. Attention has been called to this outcrop by Prof. Boyd Dawkins¹ in discussing the origin of the quartzite pebbles in the Carboniferous Conglomerate. The beds of flaggy grit or quartzite, which are stained red for some distance from their junction with the Carboniferous rocks, have a general dip southward, but are evidently much disturbed. They may with difficulty be traced north-eastward from the principal exposure for about a mile, and then seem to wedge out among softer flags and striped slates.

Belts of similar grit crop out on the opposite side of the Carboniferous basin, to the westward of the boundary fault. One of these forms the Cronnag, a low-water reef off the shore at Kentraugh, and reappears on the other side of Bay ny Carrickey, at Gansey Point and Port St. Mary harbour; and again in Perwick Bay. These are probably infolded spurs from a larger mass which occupies the high ground to the westward of Port St. Mary, extending into Mull Hill. In this locality, again, the lithological and structural characters of the strata — pale greyish grits or imperfect quartzites in flaggy bands of varying thickness, streaked in every direction

¹Trans. Manchester Geol. Soc., vol. xx., p. 54. Prof. Dawkins states the thickness of the quartzites in this section to be 632 feet, but this is evidently only an estimate based on the angle of dip and breadth of outcrop, and on the supposition that there was no structural complication in this locality.

by thin veins of quartz, and ridged up into irregular folds—bear every resemblance to those of the Agneash Grits. The prevalent dip is towards south-south-east, at angles usually between 30° and 50° .

Rocks of more argillaceous type bound these Mull Hill grits on the south, but only occupy a breadth of $\frac{1}{2}$ of a mile, after which quartz-veined flaggy grits again appear, a few hundred yards before the coast is reached, and extend into the cliff-sections of Kioney Ghoggan. This is evidently a repetition of the former mass, either by folding or faulting. In the cliffs the dip is low, rarely reaching 20° , and in one portion of the section in Bay Stacka the grits appear to rest conformably on strongly striped slates possessing a similarly low dip. The apparent stratigraphical simplicity of this section, commented on by Cumming and others, is, however, probably delusive, since the beds turn up sharply on edge a short distance inland, and the presence of an extensive recumbent fold, partly removed by denudation, like that on a smaller scale revealed in the cliff at Maughold Head (Fig. 2, p. 32), may be suspected, in which case the present superposition of the beds reverses the true order (see p. 174).

The moderate seaward dip of the strata in this section has facilitated the slipping forward of the grits over the slates in the vicinity of the cliff, thus opening the joints of the former into deep gaping fissures, known as The Chasms, which attract many visitors to this part of the coast.

These grits, along with those of Mull Hill, end off rather abruptly westward, perhaps truncated by a fault which strikes across from Bay Fine in the direction of Bay Stacka. The sections do not, however, serve to demonstrate the extent of the fault, and the disappearance of the grits might as readily be ascribed to the plunging or 'pitching' of the folds (see p. 47).

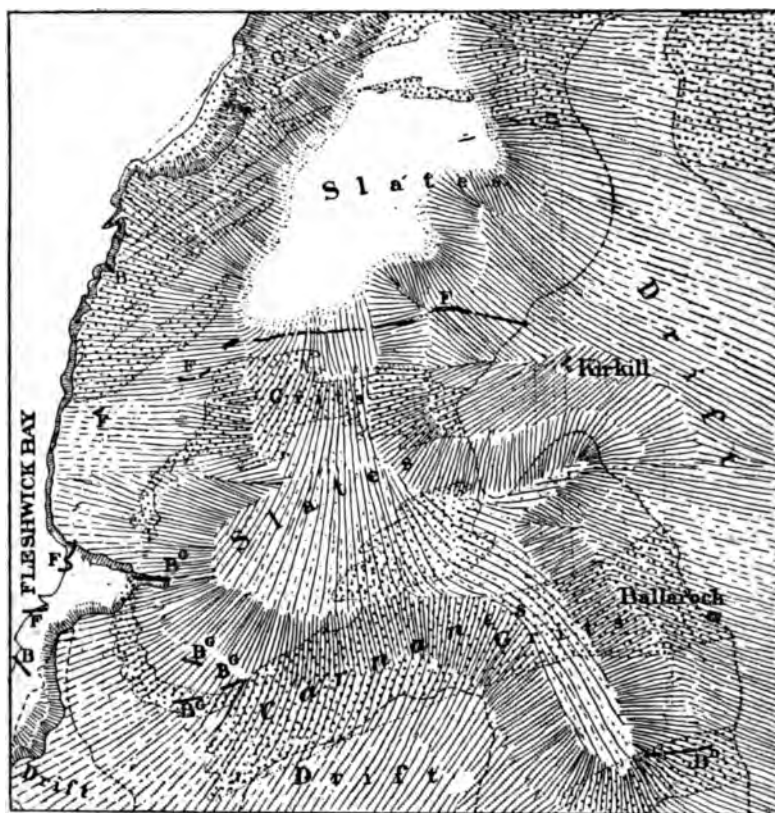
North of Mull Hill there is an interval of about a mile mostly drift-covered, in which thin-bedded argillaceous rocks appear to prevail, after which, at the northern side of Port Erin, strips of quartz-veined grit are again in evidence, and recur several times between this place and Fleshwick. The magnificent cliff-sections of Bradda Head reveal most clearly the extraordinary complications of these gritty zones among the more or less slaty beds which surround them. Differential movement around the borders of these hard bands on the westward side of Fleshwick has broken up a portion of the grit, and dispersed the fragments through a matrix of sheared slate, thus forming patches of 'crush-conglomerate' (see p. 171).

On the higher moorland ridge north of Fleshwick, extending from Carnanes to Lhiattee ny Beinne, there are excellent rock-exposures, revealing several broad belts of highly sheared grits or quartzites of the Agneash type, with intervening tracts of thinly bedded slates. This locality is very favourable for the study of the stratigraphical relations of these grits and slates as their outcrops may be traced across the plateau into the craggy precipitous slopes, 800 feet or more in height, that form

its seaward termination. It is then seen that these belts of rather steeply dipping strata, 200 or 300 yards in width on the plateau, contract when traced in the cliffs into narrow plicated bands which may not have been more than say 50 or 60 feet in original thickness. The breadth of the outcrop on the flat

FIG. 4.—*Map of coast and vicinity north of
Fleshwick Bay.*

Scale 4 inches = 1 mile.



- B Olivine-dolerite dykes (Tertiary?).
- B^D Greenstone dyke with large crushed felspars.
- B^O Altered greenstone dykes.
- F Micro-granite dyke (Foxdale Granite type), broken into segments.
The grits are represented by stippling.
- The shading indicates the shape of the ground.

ground depends entirely upon the relation of the plane of the surface to the plane of the crumpled sheet of rock, and gives no indication whatever of its thickness. In the cliffs these plicated sheets are seen to describe great curves, sweeping down to sea-level and then rising again to the surface of the plateau,

as shown in the annexed ground-plan, Fig. 4, slightly reduced from the six-inch map. Their continuity is, however, broken in places by faults or thrust planes.

From the summit of the ridge the grits appear to strike inland north-eastward, in long tongues which cross a wide drift-covered depression and then traverse the parallel ridge of Slieau Earystane, where some of the strips seem to die out; but one or two are continued into the southern slopes of South Barrule, the last traces of them being lost in a region of severe crushing and partial brecciation (see p. 169).

It is reasonable to suppose that the whole of these southern grits are portions of one and the same plicated and faulted sheet, corresponding in structural arrangement to, and perhaps once actually conterminous with, the Agneash Grits of the northern area. The difficulty found in each case in tracing the grits towards the centre of the Island may be due to some structural peculiarity affecting the rocks in the vicinity of the central valley which has not yet been unravelled, since there are complications in the arrangement of the Barrule Slates equally with the grits towards this quarter, that division also here showing a narrowing of outcrop both from the northward and southward. The complication may be in some way connected with the intrusion of the Foxdale Granite (see p. 168); or may be the result of transverse folds crossing the axes of the earlier folds. On the other hand the difficulties in question may arise simply from lateral changes in the character of the sediments.

There is a curious point in relation to the general direction of dip in the grits and thicker flags as compared with that in the more argillaceous rocks of the series which deserves careful attention. It is that the prevalent dips of the harder and more thickly bedded strata are almost invariably many degrees farther from the north and south line than are those of the more slaty rocks, even where the different types are in close proximity. In the slates the dominant dips are, respectively, about N.N.W. and S.S.E., from the opposite sides of the central axis, agreeing closely with the dominant cleavage-dips, and rarely diverging sufficiently to attain a N.W. or S.E. direction. In the grits, on the other hand, especially in the interior of the Island, north-westerly and even west-north-westerly dips are common. We also find that the orientation of the rock-masses, whether of slate or grit, as brought out by the mapping, is rarely at right angles to their general dip, but is almost always more nearly north and south than would have been inferred: that is to say, the true strike cannot be deduced from the dips alone. This peculiarity, again, is more strongly exhibited in the grits than in the slates, hence causing an appearance of unconformability between the different divisions when represented on the map, which the field-evidence shows to be misleading. This point will be further discussed when the 'Crush-conglomerates' are described.

Other eastern Grits.

On the eastern side of the Island, besides the grits already described there are some strips of similar composition lying within the boundary adopted for the Lonian Flags and apparently forming part and parcel of that division, though, as they possessed distinguishable characters, they have been separated out on the map and indicated by the grit colour and symbol. That these may represent deep isolated infolds of the Agneash Grits is not impossible, but it is more probable that they occupy a different and lower horizon, and may indeed be the oldest rocks exhibited in the Manx Slate Series. In general lithological character they for the most part resemble the Agneash Grits, but are sometimes rather darker in colour and coarser in texture.

One narrow belt of this kind is exposed among the Lonian Flags on the north side of Clay Head and may be prolonged inland, parallel to the coast, until it is again intercepted by the northern shore of Douglas Bay; and at the Nunnery on the south-western outskirts of Douglas, and again still farther to the south, similar grit-bands are found on approximately the same line of strike.

A much larger and more interesting tract of gritty rocks occurs in the cliffs and vicinity of the coast around St. Ann's (Santon) Head. Some of these grits are coarser than any other in the Manx Slate Series, being occasionally almost conglomeratic in texture. They are interbedded in thick massive bands among flaggy strata of the Lonian type. In some places, from their unyielding character, these bands when folded have burst across the bedding planes of the softer strata with which they are associated, so that the junction presents a misleading aspect of unconformity or intrusion, but in other sections it is seen that they are folded conformably with the flags. The larger particles of these grits attain to about $\frac{1}{4}$ inch (5 to 8 mm.) in diameter, and consist chiefly of bits of fine-grained arenaceous rocks, vein-quartz, felspar, etc., with a few fragments of andesitic rock. These particles are frequently drawn out into lenticles by the pressure which the rock has undergone, while little wisps of slate, sometimes an inch or two in length but only a few lines thick, scattered through the mass, seem to represent the shredding up of thin shaly partings by the same agency. These features are admirably displayed in microscopical sections of the rock, as described on a later page (98).

These coarse grits are well exposed in the rugged cliffs on the southern side of St. Ann's Head, and extend inland for 300 or 400 yards. When traced round the headland northward, they are seen to 'nose out' at the foot of the cliff in a succession of sloping anticlines, in shape like the rounded bows of upturned canoes, an appearance due to the eastward 'pitching' of the ridges of the folds, in this place at an angle of about 20° , but varying in different parts of the outcrop. Whenever tilting or 'pitching' of the folds of this kind occurs, the structure must have an important effect upon the strati-

graphy and may often be held accountable for the disappearance of beds along the line of their apparent strike. In the present example the strike of the grits at the top of the cliff would lead one to infer that they would reappear on the opposite side of the little bay, but they are carried down below sea-level in the interval by the easterly pitch of the folds.

FIG. 5.—*Idealized sketch of cliff, showing pitching of folds, based on structure seen on northern side of St. Ann's Head.*



Similar massive bands of coarse grit and quartzite, probably representing the same horizon, make their appearance in the cliffs here and there, in short disjointed segments as if cut up by faults, both to the southward of St. Ann's Head as far as the edge of the Carboniferous basin at Cass-ny-hawin, and to the northward, at Coolebegad beyond Port Soderick.

Grits west of the main axis.

The difficulty in correlating the strata on the western side of the Island with those on the eastern has been already discussed. In regard to the grits, it remains altogether doubtful

whether there be any equivalent of the Agneash Grits to the westward of the central axis, for though in this region there are some narrow belts of gritty character, these are always of limited extent as compared with the eastern tracts, and cannot be proved to occupy the same horizon.

In the north of the Island, strips of flaggy grit, with one rather massive band of quartzite which has been shown on the one-inch map, occur among the 'unseparated' rocks of the eastern coast to the northward of Maughold Head. Another wedge is seen near the margin of the 'crush conglomerate' at Claghbane, in the steep brow overlooking Ramsey. These and another strip at the headwaters of Glen Auldyn are almost certainly distinct from the Agneash Grits. But on the moorland to the westward of Glen Auldyn there is a larger patch of grey flaggy quartz-veined grit or quartzite, set in a rim of 'crush-conglomerate,' which is decidedly of the Agneash type: while in Sulby Glen, two miles farther westward, a still larger mass of similar grits is revealed in the high crags which border the valley on both sides.

On the western slope of the Sulby valley the last-mentioned grits ascend to the summit of Mt. Karrim (1,084 feet), flanked on the east by the main mass of 'crush-conglomerate,' and on the west by 'unseparated' slates and flags. The violent contortions into which the strata have been thrown in this district are admirably displayed in the craggy walls of the valley (see p. 61, Fig. 7).

Another strip of grit, probably a repetition of that last described, occurs two miles farther up the same glen, between Craigmooar and Druidale; this also is fringed in places on the east by 'crush-conglomerate.'

Near the head of Glen Dhoo, the next valley to the westward of Sulby Glen, an ill-defined belt of gritty rock, shown on the map, is revealed, which is of different character from the above, more closely resembling the arenaceous part of the Lonan Flags than the Agneash Grits; but it has been much altered from its original aspect by shearing (see Fig. 26, p. 81). There are other smaller patches of similar composition among the 'unseparated' rocks of this part of the Island, which could not be shown on the map. Still farther west, on the outer slope of the mountains, a gritty zone may be traced, with many interruptions and intercalations, from the western flank of Slieau Curn south of Ballaugh, to Kirk Michael, and thence along the edge of the hills to Ballakaigen. Its constituent strata are, however, often of the muddy greywacke type and not pure grits; and, as mentioned on a former page, these may represent the Niarbyl Flags of the country further south.

About a mile to the southward of Ballakaigen another wedge of grit sets in, nearly on the same line of strike as the previous belt but of different lithological character, and is prolonged from Knocksharry to Poortown along the crest of the ridge that borders the Peel Sandstones. It includes some massive quartz-veined bands, and also, near its northerly termination at

Creggan Mooar, a highly sheared coarse grit somewhat resembling the St. Ann's Head rock, with particles three or four mm. in diameter, among which are bits of andesite. In hand-specimens this bed has somewhat the aspect of an ash, but it appears to be a true grit. (See petrographical description p. 99.)

Flaggy grits are visible in many places in the interior of the Island between the two belts of Barrule Slate, especially at the lower levels, but are not often well-exposed, or sufficiently traceable to be shown on the one-inch map. They are often associated with arenaceous mudstones, scarcely to be distinguished from the grits but without the criss-cross quartz-veining and possessing in other respects the characters of the flaggy divisions. The gritty belt shown on the map at Dreem-beary, a mile to the eastward of Glen Helen, is of this nature; and likewise the strip occurring south of the central valley, in Glen Rushen, and striking thence to the western coast south of Niarbyl Bay. It is doubtful whether these rocks should be classed with the Grits or with the Flags.

The narrow belt seen on both sides of the central valley about a mile to the eastward and south-eastward of St. John's, in quarries where it has been worked for road-metal, is of different character. Its chief constituent is a hard splintery dark blue rock, somewhat pyritous, composed of an admixture of coarsish sand and fine argillaceous material, occurring in layers one to two feet thick, with slaty partings. (See p. 164.)

The relations of these grits to the other divisions will be further discussed on a subsequent page.

The Barrule Slates.

This division where developed in force is lithologically the most distinct and stratigraphically the most persistent member of the Manx Slates, and has therefore an especial value for the student of the series. It consists of dark blue, somewhat altered clay-slate, and is traceable, with scarcely an interruption, through the main hill-chain of the Island from coast to coast. From its homogeneous composition, and from the shearing which it has undergone, its original bedding planes are rarely distinguishable excepting where the rock is polished by wave or stream action, and even then are sparingly revealed. Its weathering and fracture are determined by the secondary planes of strain-slip which have been imparted to it by earth-movement. These planes are frequently glossy from the sericite which has been developed upon them, and the rock then deserves the term "phyllite," which has been applied to it by Prof. Dawkins.¹

This shear-structure is so predominant in the rock that its apparently homogeneous character may be partly due to its argillaceous strata having been kneaded and squeezed together

¹ Trans. Manchester Geol. Soc., vol. **xx.**, p. 53.

so that the original lamination has been lost. Under such conditions it is even possible that a mass resembling the Barrule Slates might be produced from some of the striped slates of the 'unseparated' areas. But while it is clear that patches of these banded strata have been drawn out and mingled inseparably with the margins of the Barrule Slates, the general tenor of the field-evidence is fairly convincing for the original identity of the division as a separate member of series, of which the limits can be delineated on the map, though somewhat diagrammatically.

Where bounded by 'crush-conglomerate' the margin of the Barrule Slates is fairly well-defined, but elsewhere it usually fades off, by imperceptible degrees or by alternations, into the paler colour-banded 'unseparated' beds. There are two distinct and more or less parallel belts of rock of the Barrule Slate type, of which the more easterly, in the principal hill-range, is the more continuous and better defined. These, along with other smaller subsidiary strips, are probably portions of a once-continuous mass.

With the exception of obscure worm-like markings, which may or may not be organic, no fossils have hitherto been found in the Barrule Slates, unless we consider the outlier of slate on Cronk Sumark near Sulby to belong to this division, where Mr. Bolton obtained the remains described on p. 93. Some dark iron-stained bands in the series have been searched without success for graptolites (see p. 94).

The microscopical structure of these Slates, and the changes effected in them in many places by metamorphic agencies will be discussed under a subsequent heading (see pp. 99 & 110).

The homogeneous aspect and fissile structure of the rock has encouraged many futile attempts in the past to develop quarries of roofing slate in it. Enterprises of this kind were especially numerous about 35 years ago, when large sums were expended in making openings into the Barrule Slates in every part of the Island. But these enterprises all proved failures and were sooner or later abandoned with heavy loss, the saleable slate obtained being very limited in quantity and poor in quality (p. 559). Indeed if the uncertain character of the cleavage and its close dependence upon the planes of shear-movement had been understood, no other result than failure could have been anticipated, especially in a rock so frequently traversed by quartz veins and zones of crushing.

Main Belt of Barrule Slates.

From the coast near Ramsey at the north-eastern corner of the massif, we may trace this belt into the steep mountain-ridge which commences in North Barrule and continues to Snaefell, a distance of four miles. The physical characters of this ridge correspond with the structural features of the slates, the steep craggy south-eastern side being due to the outcrop of the

schistose planes, perhaps in part coinciding with the original bedding, while the grassy north-western slope marks the direction of dip of these planes.

The slate is traversed at frequent intervals by segregation-veins of quartz, of all sizes up to 5 or 6 feet in breadth. These are usually more or less lenticular, and have generally been crushed and drawn out with the country-rock. They often include small quantities of yellow mica, chlorite and other minerals; and the crushed slate around their margins sometimes contains garnets and other alteration products, apparently developed by the differential movement (see p. 111).

While the Slates form the whole of the high ground of this hill-chain, they do not reach down into the valleys on either side, and where a partial transverse section of the ridge is presented we find that the outcrop of the slate is contracted as it descends to lower levels. The same relation between breadth of outcrop and altitude of ground holds good through the whole extent of this belt of slate, and tells strongly in favour of the view that in spite of the apparently persistent north-westerly dip, the slates occupy a synclinal trough.

A good illustration of this structure is found in the south-westward prolongation of the belt between Snaefell and Beinn y Phott the next summit of the range, where its outcrop descends to below 900 feet in crossing the deep intervening glen, and is there contracted to a breadth of 200 or 300 yards, expanding again to over half a mile on Beinn y Phott and its continuation Garraghan, once more to shrink to less than its breadth in the former glen in crossing the valley of the Glass near Injebreck at an altitude of about 500 feet. When it ascends from the last-mentioned valley into The Creg (Creg y Whuallian,¹ 1,344 feet), a spur of Colden Mountain, its expansion at the higher level is not so well marked, which may be partly explained by the almost precipitous steepness of its outcrop in this ground but is also in keeping with that general contraction which the belt undergoes in approaching the central part of the Island, a structure already mentioned as being there equally visible in the Grits. On the eastern slopes of Slieau Ruy, and in Greeba Crag overlooking the central valley, the belt dwindles to an irregular contorted strip, scarcely recognisable among the partly brecciated colour-banded slates and thin grits which appear to constitute the greater part of these exposures; but the whole of the rocks have been crushed in this quarter into an almost inseparable mass.

Half a mile to the westward of this outcrop, on the opposite or western slope of Greeba Mountain, another strip of dark slate of the Barrule type is found, which wedges out rapidly northward, but expands southwards. This is interrupted by the

¹The ridge so named on the six-inch Ordnance map should probably be written '*Creg Awhallan*,' after a farmstead of that name at its foot. It must not be confused with the '*Creg y Whuallian*' south of the central valley at Greeba, nor with '*Slieau Whuallian*' south of St. John's.

central valley, but seems to reappear on the southern side, where it has a width of over half a mile, and is prolonged thence south-westward, across Kerrowgarroo, for two miles farther. It then descends into the Foxdale Valley much contracted in width, and wedges out on the western side of the depression. The position of this strip in regard to the former belt may be interpreted to indicate a subsidiary trough of the synclinalium.

The prolongation of the main belt across the central valley is not so readily followed, there being great confusion and irregularity of structure on the southern hill-slope opposite to Creg ny Greeba. There does, indeed, exist a patch of altered dark-blue slate of the Barrule type on the crest of that slope, but it appears to be discontinuous, wedging out in both directions; and moreover, instead of its dominant structural planes presenting the usual dip towards N.W. or N.N.W., they possess for the most part the unusual direction of, approximately, N.E. This divergence of dip and strike is accompanied by a marked augmentation of the schistosity and mineral alteration of the rock, a matter to be subsequently discussed (see p. 111).

Hence in trying to trace the main belt southward from the central valley, it is not until we have followed its previous direction of strike for two miles, and have begun to ascend the eastern slope of South Barrule beyond Foxdale village, that we can confidently again identify the Barrule Slates. Their reappearance in recognizable form is coincident with the sharp increase of altitude, the mountain rising 700 or 800 feet above the country to the eastward, to a total height of 1,585 feet. In this hill the Barrule Slates regain all their characteristic features, and their expanded outcrop, nearly a mile in width, occupies the summit and most of the western slope. Thence they may be followed along the same ridge through Cronk Fedjag to Cronk ny Arrey Lhaa, 1,449 feet, maintaining their width of outcrop at the high levels but contracting to at least one half as they plunge down to sea-level in the terminal precipices of the ridge on the western coast. These precipices afford the grandest transverse section of the division to be found in the Island, but unfortunately, from their inaccessibility, only a very small portion of the section can be studied.

Barrule Slates north-westward of the main belt.

We now return to the northern part of the massif, to examine the areas to the north-westward of the belt above described in which dark slates of the Barrule type prevail.

Nearest to the northern part of the main ridge, we find an isolated patch of irregular outline, out of which the middle portion of Glen Auldyn is carved. This tract of dark blue slate is rimmed on the west, north and north-east by 'crush-conglomerate,' and on the south-east by 'unseparated' flaggy

strata. A little farther westward a larger tract of similar composition, also bounded in the same quarters as the last by 'crush-conglomerate,' occupies the high moorland of Slieau Monagh (or Meanagh; 1,257 feet), and extends in long tongues, north-north-eastward and south-south-westward, from the head of Glentranmon to Sulby Glen.

Among the rocks left as 'unseparated' in the broad area to the westward of Sulby Glen, there are some narrow strips which may belong to the Barrule Slates, but scarcely sufficiently characterized for definite recognition. When, however, we cross the bold outer ridge of the Island which forms the western rim of the Sulby basin, we reach a more extended development of the slates. Commencing in a tapering belt on the western side of Slieau Freoaghane, and expanding rapidly southward to a width of three-quarters of a mile or more on Sartfell the next summit of the ridge, the band apparently continues of about the same width across the lower drift-encumbered ground to Glen Helen, and thence, occupying both sides of the Neb valley, to the central depression in the vicinity of St. John's, a distance in all of six miles. Though interrupted by the central valley, the same belt of dark blue slate seems to be prolonged on the opposite side, as noted by Clifton Ward,¹ rising again abruptly in the steep gable-end of Slieau Whuallian (alt. 1,094 feet), and rapidly attaining the same breadth of outcrop as before.

It may then be followed south-westward along the ridge and across the transverse gash of Glen Rushen, into the moorlands of Dalby Mountain, where it is about a mile wide, and thence to the western coast. It narrows suddenly in descending from the high land, and before reaching the shore at Fheustal, on the south side of Niarbyl Bay, splits into a series of obscurely defined strips a few hundred feet in breadth, again illustrating the general tendency of the division to wedge out downwards. Throughout this belt the dominant structural dips are, like those of the former bands, towards N.N.W.

It is to be noted that, while in the northern part of its course there is a space of over four miles between this belt and that of the Snaefell chain, the two gradually converge southward until only three-quarters of a mile apart in the vicinity of the western coast. It will be observed, too, that the isolated strips in the centre and north of the Island are set *en échelon* to each other and to the principal belts, and again, that the incoming and rapid expansion of the north-western belt is concurrent with the contraction of the main belt in the central district of the Island. Like the downward narrowing of the outcrops, these phenomena seem to imply that the slates occupy a succession of irregular troughs.

In any case, the arrangement of these belts of slate is proof that the structural axis which divides the dominant south-south-easterly from the dominant north-north-westerly

¹ Geol. Mag., dec. ii., vol vii., p. 2.

dips cannot mark a simple stratigraphical anticline as hitherto supposed, since they all lie on one—the north-western—side of this axis, with their planes of fissility throughout dipping in the general N.N.W. direction. If the axis had been a true anticline, the Barrule Slates must, of course, have been repeated on its south-eastward flank, in the district where only grits and flags are to be found.

It is, however, possible that the arrangement of the Barrule Slates in the different belts may be due in part to normal faults, or to planes of overthrust, since we know, from their faulted junctions with the Carboniferous rocks and from other evidence in connection with the mineral lodes, that many unrecognised normal faults must traverse the series, and that indications of overthrusting on a more or less extensive scale are prevalent throughout. But while it must be acknowledged that both these factors are likely to have produced greater effects than is here assigned to them, the constant association of the margin of the slates with the striped or banded beds which apparently mark a passage into the flaggy or gritty deposits, seems to show that the junctions are for the most part simple; and it has been considered desirable, therefore, to avoid further complicating the subject by introducing faults where definite proof was lacking.

Strata of the 'Unseparated' Tracts.

Brief mention will suffice for these tracts, since the general characters of the rocks of which they are composed have been incidentally stated more than once in the foregoing pages, and fuller local information will be given hereafter in the chapter of topographical details.

The predominant strata are intermediate in character between the slates and the flags, being usually composed of alternating laminae of impure argillaceous and fine-grained arenaceous material, often in vividly contrasting blue-black and pale grey tints, while thin bands of grit or quartzite, both isolated and in groups, recur at frequent intervals.

These rocks pass gradually on the one hand into the grits and flaggy greywackes, and on the other into the smooth argillaceous slates; and in their original position they have no doubt marked the vertical upward passage from the sandy to the slaty divisions. In these strata, so long as any vestige of their original bedding remains, every plication and fracture which has affected them is brought out with the greatest distinctness, and they consequently afford admirable material for the study of the movements by which the rocks have been affected (see p. 73).

Here and there in these tracts occur thin lenticular belts of more peculiar type, which have been referred to on a previous page. Among these, the handsome banded pale- and dark-green slate exposed on the foreshore in Niarbyl

Bay and at Port Lewaigue, and the strongly striped light-grey laminated strata of the upper basins of the Sulby and the Neb, best deserve mention as likely to prove traceable, though the present investigation failed to follow them for more than a short distance (see pp. 123, 149).

The 'Crush-Conglomerates.'

Though as essentially the result of earth-movement as the strain-slip cleavage and other secondary rock-structures subsequently to be discussed, the 'crush-conglomerate' requires distinctive consideration by reason of its having been developed in such a manner and on such a scale in some parts of the Island as to form a separable zone among the rocks (see Map, Fig. 29). In the areas referred to, its boundaries have been independently traced out, and are shown on the one-inch map.

Previous to the present Survey, the true character of the structure had not been recognised, and it was supposed to represent either a true slate-conglomerate or a volcanic breccia. References to it are, however, curiously rare in the previous literature. Henslow in 1820 gave a faithful description of one of the sections in the following terms:—"Near Balla Neah [Ballanayre of the Ordnance Map, on the west coast north of Peel], I observed the cliffs to consist of angular fragments of clay-slate embedded in a clay-slate paste, and what is curious, these fragments are scarcely to be distinguished from the base excepting on the surface of the rock which has been exposed to the action of the waves, where they become sufficiently apparent by the fragments assuming different tinges of colour, giving the specimen a mottled appearance."¹ Among the later literature we find one or two obscure references to 'volcanic breccias' in the series, with which these rocks seem to have been included; and in 1893 Mr. H. Bolton² described a portion of them in the following passages:—"In the neighbourhood of Ballure Glen and Ballastowel Hill [near Ramsey], the slates are badly bedded, and full of irregular pebble-like inclusions, which give to the rock a brecciated appearance. These have yielded the cast of a trilobite much resembling *Asaphus* or *Eglina*, and also certain other structures which may possibly prove organic. North and north-west from Ballastowel, the Skiddaw Slates

¹ The presence of this structure in the Isle of Man was first recorded by W. W. Watts and the author in a paper on "The Crush-Conglomerates of the Isle of Man." *Quart. Journ. Geol. Soc.*, vol. li. (1895), pp. 563-597. Passages in the following pages taken verbatim, or nearly so, from that paper are marked by single inverted commas.

² *Trans. Geol. Soc.*, ser. i., vol. v., p. 490.

³ Report Brit. Assoc. for 1893, p. 771.

consist of irregularly bedded iron-stained slates with interbedded volcanic ash, the latter often of considerable thickness."¹

It is now recognized that conglomeratic rocks of this character, due to the breaking up of the strata under shearing pressure, are of common occurrence in all parts of the world where strata of variable lithological characters have undergone severe movement, and the term "autoclastic" has recently been applied to them.² The following is the definition of the structure given by Prof. C. R. Van Hise in his "Principles of North American Pre-Cambrian Geology."³

"When rocks are folded by strong orogenic forces, and they are not so heavily loaded as to render them plastic, they are frequently broken into fragments, and 'autoclastic' rocks are produced. The autoclastic rocks which readily show their origin may be called *dynamic breccias*, and those which resemble ordinary conglomerates may be called *pseudo-conglomerates*. Brittle rocks are the most likely to become autoclastic; hence it is that cherts, quartzites, cherty limestones, graywackes, and rather siliceous slates are some of the kinds which most frequently present the phenomena described. The movements of the broken fragments over one another in many cases so thoroughly round them that they have the appearance of being waterworn, and the matrix between the larger fragments may consist almost wholly of well-rounded fragments of a similar character. For instance, in a semi-indurated quartzite the larger complex fragments may be well rounded by their mutual friction while the matrix may consist of the simple original waterworn grains which are rent apart. In another case the original rock may have consisted of beds of mud interlaminated with thin beds of grit.

"By consolidation and cementation these beds may have been transformed to alternating shale and graywacke. The shale is plastic under light load; under the same load the graywacke is brittle. When such a set of beds is deformed the shale yields largely by flow and the graywacke by fracture. The beds of graywacke are broken into fragments of varying sizes, which are ground over one another, and thus are rounded. At the same time the shale flows and fills the space between the fragments. Also slaty cleavage may be developed. As a result, a pseudo-slate-conglomerate is produced,

¹The "interbedded volcanic ash" of this description is part of the crush-conglomerate. Compare also Mr. Bolton's paper "On a trilobite from the Skiddaw Slate of the Isle of Man." *Geol. Mag.*, dec. iii., vol. x., p. 29. (Jan. 1893.)

²See "Structural Geology of Steep Rock Lake, Ontario," by H. L. Smyth (*Am. Jour. Sci.*, 3rd ser., vol. xlii., p. 331). In this paper the author defines "autoclastic schists" as "schists formed in place from massive rocks by crushing and squeezing without intervening processes of disintegration or erosion, removal and deposition."

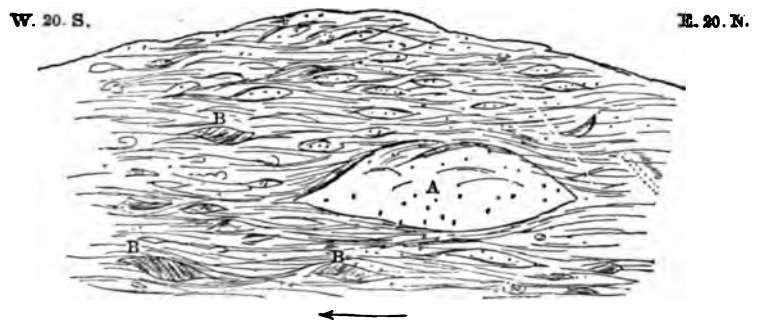
³Sixteenth Annual Report of U.S. Survey, pt. 1, p. 679. (Washington, 1896)

having a slate matrix and pebbles of graywacke, which, so far as its own characters are concerned, could not be discriminated by any one from a true conglomerate. Fortunately, in most cases it is possible to find transition phases between such a rock and one in which the process has not gone so far, and thus one is enabled to determine that the rock is autoclastic."

This description of the structure as it occurs among the Pre-Cambrian rocks of the Lake Superior region in North America, which had not been published at the time of our investigation of the Manx examples, applies in every particular

FIG. 6.—*Crag of Crush-conglomerate at the southern edge of Cronk Sumark, Sulby; showing fragments of grit, fine-grained flag-stone, and hard clay-slate, in a matrix of bluish slaty material.*

(From Quart Journ. Geol. Soc., vol. li.)



- A. Block of sheared slightly felspathic grit, about 8 feet long.
 - B. Fragments in which the original bedding is still visible.
- The arrow indicates the probable direction of the movement during shearing.

to the 'autoclastic' or 'dynamic' conglomerates of the Isle of Man.

Where typically developed, in the north and north-west of the Island, the breccias form thick masses of imperfect conglomerate, made up of irregular scattered fragments set in a slaty matrix. 'The fragments vary in composition, but most frequently are of fine-grained grit or sandstone and of sandy slate, with less abundant pieces of coarsish grit, of banded flaggy slate, and of purely argillaceous smooth blue slate or shale. These fragments are usually phacoidal or lenticular in outline (hence appearing rounder in transverse section than they really are), but the shape varies with the size, and also differs in different places. In some localities many of the smaller inclusions are well-rounded, while in others they take the form of subangular or spindle-shaped strips (see Figs. 6, 9, 12, 23). The fragments are of all sizes, from blocks several feet in diameter to particles of microscopic dimensions. They are, as a rule,

indiscriminately mingled, large and small, in a highly sheared slaty matrix; but the average size of the inclusions varies greatly in different localities, and there is sometimes a total absence of the larger fragments.'

These characters are well illustrated in the weathered exposures on Cronk Sumark, near Sulby Bridge Station, from which the figure on p. 57 is taken.

'A glossy sericitic face, due to shearing, coats the harder inclusions, and planes of similar character are abundant throughout the matrix, and sometimes cut the fragments. These schistose planes determine the weathering and the fracture of the rock, and when, as frequently happens, they lie very close together and the inclusions are all of small size, the fragmental character of the mass is not evident in ordinary exposures, and needs a fresh cross-fracture to reveal it. There is usually an abundant development of iron pyrites in the rock, sometimes finely disseminated, and sometimes, as in the quarry-section on the eastern side of Cronk Sumark, in cubical crystals from one-eighth to one-quarter inch in diameter, which have been affected by a later movement than that which formed the conglomerate. Such is the composition of the rock over large areas.'

Distribution of the Crush-conglomerates.

As stated in the earlier part of this chapter, indications of shear-fluxion and partial brecciation are exhibited by the Slate Series in every part of the Island; but these become greatly intensified on the north-western side of the structural axis, particularly where, in this quarter, the more thinly-banded rocks lie in the proximity of masses of grit. We also find that the disturbance of the bedding increases in severity as we follow the strike of the rocks from south-west to north-east.

In the southern part of the Island, the occurrence of actual 'crush-conglomerate' is confined to a few isolated strips bordering detached portions of grit, as in the instance already described on the western side of Fleshwick (see p. 43), and in similar examples on the foreshore near Gob yn Ushtey north of Cronk ny Arrey Lhaa, and on the eastern slope of South Barrule.

Northward of the central valley the structure is first developed slightly near the southern termination of Creg ny Greeba. Then, two miles farther north, it is next found in strong force in the depression on the northern side of Lhargee Ruy, and here first begins to form a definite belt. The exposure just mentioned occurs in the bed of a feeder of the River Neb near its source on the western side of Colden Mountain, and exhibits slaty breccia, crowded with subangular and lenticular fragments of fine grit and pale slate up to 6 inches in length, in a zone of about 100 yards in breadth.

The persistent drift-covering of the surrounding moorlands

hides the prolongation of the belt, but some traces of it are visible on Slieau Maggle (the hill nameless on the one-inch map, next west of Injebreck Hill) and its line of strike points exactly for the most southerly exposure of the great belt of Sulby Glen, which occurs three miles north-north-eastward, in the bed of a rivulet draining into the Druidale branch of the Sulby River, west of the ruined farmstead of Close, where the conglomerate is 150 yards in breadth. The outcrops of the structure expand rapidly in width in Sulby Glen, and are practically continuous from the above mentioned exposure to the mouth of the valley, a distance of five miles. As the most typical sections occur in the northern portion of the belt, we will pass at once to the mouth of Sulby Glen, and thence trace the belt back southward, and also eastward.

The structure is well exposed on the eastern side of the entrance to the Glen, in the prominent hummock of the Slate Series known as Cronk Sumark or Primrose Hill, which rises steeply above the drift plain. Some low crags near the north-western base of this hill reveal a highly contorted strip of rather coarse-grained massively-bedded grit, and 40 or 50 feet higher on the same slope a large quarry has been excavated, in obscurely-cleaved dark blue slates welded into a mass, in which indistinct traces of folded bedding alone remain in the upper part of the section, while the lower part gradually changes into a slaty breccia. In crags outside the quarry, below the level of its floor, the breccia is continued downward towards the strip of grit, and there contains many gritty inclusions. It is from the talus of this quarry that Mr. Bolton, obtained the specimens described on p. 93. The 'crush conglomerate,' full of grit fragments, some of large size as shown in Figure 6, p. 57, extends from this place to the eastern edge of the hill, where, behind the farm-yard of Grangee, it has been quarried for building-stone, the later shear-planes being sufficiently developed to give a rudely flaggy character to the rock. From Cronk Sumark, so far as we can judge from the exposures, the autoclastic structure extends in a more or less continuous sheet southward and eastward for more than a mile though the brecciation is sometimes imperfect and there are a few strips in which the bedding has not quite disappeared. In the quarried crag at Kerroomoar, half mile to the east-north-east of Cronk Sumark, the conglomerate is traversed and altered by two igneous dykes of widely different ages; the older, a dioritic rock probably belonging to the Pre-Carboniferous 'greenstone' group, is intersected by the newer dyke, one of supposed Tertiary olivine-dolerites (see p. 105). To the southward of this place the breccia can be traced in exposures here and there in the roads, and in small bosses in the fields, until it enters Narradale, where it occupies the stream-bed for nearly a mile, traversed by several 'greenstone' dykes and interrupted by occasional intercalations of bedded slate. In the right bank of this stream, south-west of the only farmstead in the upper part of the glen, there occurs a boulder-like mass of coarsish grit or quartzite, apparently embedded in the crush-conglomerate, which measures, in its ex-

posed portion, 14 by 8 by 6 feet. Its partially rounded surface has a thin smooth sericitic coat, with little patches of the breccia adhering to it, but the shearing seems to have been confined to this crust, since petrological examination of the layer immediately beneath gave no indications of movement (see p. 104). This is the largest single boulder which has been observed in the crush-conglomerate of the Island, though the structure often isolates and surrounds irregular patches of disturbed but still continuous strata of very much larger dimensions.

On the high-lying land to the eastward, between Narradale and Glentramman, which rises from about 300 feet to nearly 800 feet above sea-level, the autoclastic structure is exhibited in scanty exposures, but seems to split up into narrow strips and end off before reaching the latter glen, in which, however, the stream-sections are extremely difficult of access and have been only partly examined.

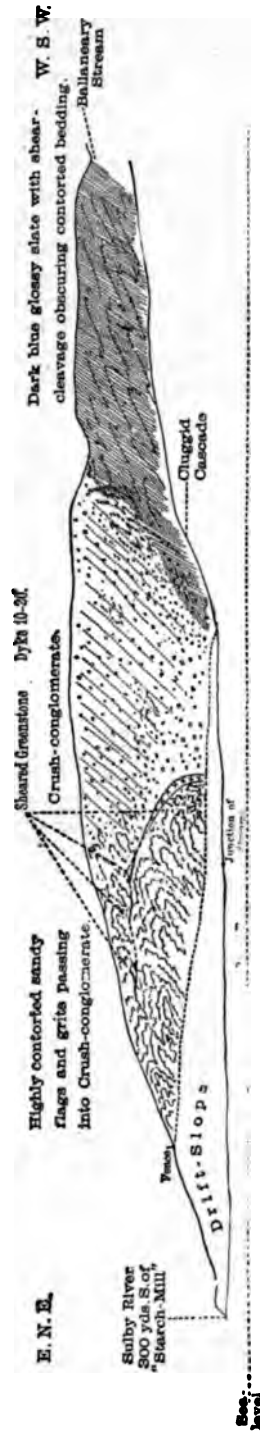
In the opposite direction, the conglomerate may be traced westward from Narradale into the bed of the stream of the next glen, where it is often very coarse in texture; but it is less distinctly represented in the short valley draining to Ballamanaugh, one-third of a mile farther west, which seems to lie somewhat to the northward of the zone of brecciation. The southerly margin of the belt is reached in the streams near Cronkgarroo, (the more northerly of the two places of that name on the one-inch map) and then, following the line of south-westerly strike for 400 or 500 yards across grassy moorland, we descend at Ballaneary into the valley of a tributary of the Sulby River, where a deep gully has been cut in compact dark slate of the Barrule type, from which the stream falls into Sulby Glen in a picturesque cascade known as the Cluggid.¹ Below the cascade, paler banded slates with a partially brecciated structure are revealed, and less than 100 yards lower down these pass into pebbly crush-conglomerate which forms the bed of the stream. The same phenomena are beautifully exhibited in the craggy walls of the great glen, which rise 500 or 600 feet high on the northern side of the water-course, furnishing a continuous section across the strike of the brecciated zone, as indicated in the opposite figure.

Nowhere can the development of the structure and its relation to the accompanying strata be more satisfactorily studied than in these crags. The width of outcrop of the crush-conglomerate is slightly over 400 yards, and its vertical depth exceeds 500 feet, the top being lost in the grassy ground above the valley. South-eastward, it passes gradually into the dark Barrule Slate of Ballaneary; and north-westward, into highly contorted banded slaty and gritty flags and quartz-veined grits which constitute the northerly termination of the section and are excellently displayed in the opposite or western wall of the Sulby valley.

¹ This name is not recorded on the Ordnance maps. It is said to signify "a throat," and to apply particularly to a natural perforation in the rock through which the stream drops in one part of its fall.

FIG. 7.—Section across the zone of *Crush-conglomerate* on the eastern side of *Sulby Glen*.
(From Quart. Journ. Geol. Soc., vol. li.)

Scale, horizontal and vertical : 6 inches = 1 mile.



The section is not drawn strictly vertically, as it combines all the outcrops of the hill-side which slopes at about 40°.

Every stage in the breaking up of these sandy slates and grits can be distinctly traced. Amid the mass of the breccia there are isolated patches of unbroken or only partly broken strata, from a few feet to a few yards in diameter; while at its margin narrow strips of disrupted rock are interbedded with comparatively unbroken bands, as though the structure had pushed its invasion more readily along some beds than others. In a few instances, well-defined included fragments are themselves composed of breccia differing in texture and tint from that in which they are embedded, as though portions already in the state of crush-conglomerate had been broken up a second time. Occasionally, also, there is a distinct U or V-shaped arrangement of the longer axes of the fragments, as shown in Fig. 8, suggestive of sharp folding of material already crushed.

FIG. 8.—*Part of a crag in Sulby Glen (100 yards north of "Limekiln," Glen Mooar, of 6-inch map, Sheet 4).*

(From Quart. Journ. Geol. Soc., vol. li.)

Length, about 3 feet.



The fragments in the crush-conglomerate are of pale greyish flagstone or fine grit, up to 3 inches in diameter, the larger of which show an arrangement suggestive of a recumbent fold.

Movement subsequent to the primary brecciation is also proved by the strain-slip or 'shear-cleavage' which frequently affects the crush-conglomerate equally with the neighbouring unbrecciated rocks, and with the same direction and dip. The fissile planes of this cleavage traverse matrix and inclusions alike, except that when the latter are of hard grit the planes sometimes swerve around their edges in a fashion which demonstrates that the fragments held their present position before the fissility was imparted to the rock. These phenomena are perhaps best displayed in sections two miles higher up the valley, whence the following illustrations, Figs. 9 & 10, are taken.

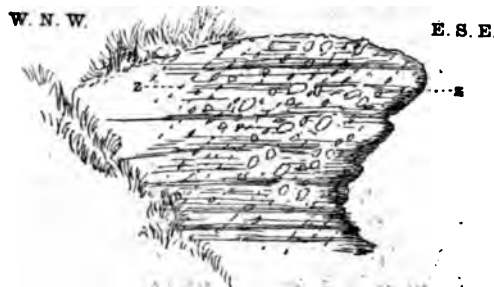
Where the conglomerate is chiefly made up of slate with few hard inclusions, this fissile structure is as strongly developed as in the Barrule Slates and renders the fragmental character of the rock almost invisible.

In the crags east of the Cluggid, an intrusive dyke of diabase (see Fig. 7; also p. 133), from 10 to 20 feet thick, crosses the

FIG. 9.—*Sketch of crag of Crush-conglomerate on northern slope above Druidale stream, at junction with Sulby River.*

(From Quart. Journ. Geol. Soc., vol. li.)

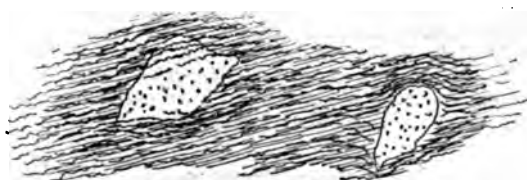
Length, about 3 feet.



Z—Z. Shear-cleavage planes, developed subsequently to the brecciation, and obliquely to the linear arrangement of the grit-fragments, which show a prevalent dip to north-west. The dip of the shear-cleavage is N. 20° E. at 35°, the section being along the strike.

FIG. 10.—*Enlarged view of Crush-conglomerate in crag adjacent to that shown in the last figure.*

About one-half natural size.



The shear-cleavage planes traversing the shaly ground-mass partly swerve around and partly cross pebble-like fragments of fine-grained grit.

brecciated belt and is prolonged among the unbroken flags to the northward. This dyke, though not so much affected by shearing as those in Narradale, affords further evidence of post-brecciation movement.

In the country to the eastward of Sulby the belt of crush-conglomerate appears to lie approximately flat or only gently inclined, and its outcrop is therefore broad; but in Sulby Glen it seems to have a steepish north-westward dip or pitch, and

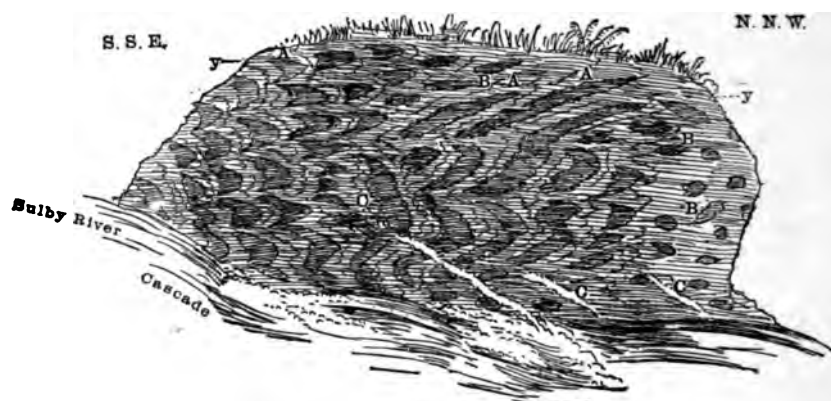
therefore, though its thickness may not be diminished, its outcrop is narrower. Its limits are not, however, so regular that the mode of occurrence of the zone in this respect can be determined with certainty; but whatever its position may be, it is evident that its thickness must be considerable, since its outcrop in this part of Sulby Glen measures from 200 to 400 yards in horizontal extent and has a vertical range of 200 to 500 feet in the precipitous slopes.

Southward from the Cluggid, in the portion of the Sulby valley named Glen Mooar on the Ordnance map, the 'crush-conglomerate' occupies the lower slopes on both sides. But

FIG. 11.—*Passage of banded slate into breccia in crag forming western bank of Sulby River under cottage west of Slieaumonagh.*

(From Quart. Journ. Geol. Soc., vol. li.)

Length, 12 feet.



Firm flaggy slates with well-marked blue and grey banding, A, A, A; highly contorted in the centre and left side of the crag, and broken up into fragments, B, B, B, in a slaty matrix on the right and upper part. The thickness of the bedding is exaggerated in this figure. C, C, C, Quartz veins, 2 to 4 inches thick, disturbed and twisted, but not participating in the brecciation. y—y Later shear-cleavage.

where the river makes a sharp elbow eastward, under the upland farmstead of Killabraggah, the belt of breccia strikes across into the western bank, so that both its upper and lower limits are contained in a single range of precipitous crags, showing its vertical depth to be between 250 and 350 feet.

The above section (Fig. 11), on the margin of the zone where it crosses the river, exhibits the transition from bedded rocks into breccia.

Thence the belt can be traced across the rocky shoulder of Craigmooar, and comes down into the valley again at the school-house of Tholt-e-Will (adjacent to "Chapel" of Ordnance map), still flanked on the west by grits and

on the east by Barrule Slates. Meanwhile a subsidiary strip of the conglomerate, apparently wedging out both northward and southward, occupies the eastern slope of the Sulby valley around Ballaskella, possibly representing the emerging crest of a sharp fold in the brecciated zone.

Half a mile south of Tholt-e-Will the structure in all its phases is admirably displayed in the bed of the Sulby, under Druidale farm, and in the adjacent craggy ground around the confluence of tributary streams from both sides. It here occupies a zone fully 500 yards in breadth, but this includes certain bands in which the bedding-planes are only partially disrupted, and the belt is also complicated by faulting. Its component materials are chiefly slaty flags, broken and drawn out into irregular lenticles which often still preserve traces of the original bedding. The shear-cleavage, as already noted, is strongly developed throughout the mass.

The higher or Druidale portion of the main valley above this place swings to the westward of the conglomeratic belt which however is displayed for 300 yards in the bed of the side-stream, Glen Crammag, whence its south-westerly strike probably carries it under the drift-covered moorland, for 600 yards, to its final exposure in the Sulby basin, in the bed of the rivulet west of Close, as already described.

These Sulby Glen sections thus afford satisfactory evidence that the autoclastic structures are continuous for a distance of at least six miles. Moreover, there is no reason to doubt that, before the truncation of the Manx Slate massif by denudation, the belt has once extended farther northward, —probably much farther, since the maximum development of the conglomerate is attained at the extreme northerly border of the hills.

There are further developments of the structure to the eastward of the great Sulby belt, apparently on the same stratigraphical horizon, and once perhaps continuous with it, but now reduced by denudation to a series of isolated wedges set *en échelon*. The western border of the most westerly of these wedges, on the slope south of Lezayre Church, approaches within half a mile of the eastern termination of the Sulby belt at Glen-tramman, and extends thence into the summit of Skyhill between Lezayre and Ramsey. The weathered crags on the northern crest of this hill show very clearly the gradual disruption of grit-bands; while farther south on the ridge three, or possibly four, separate strips of crush-conglomerate, each narrower than the last, may with some difficulty be traced, with intervening wedges of more or less unbroken strata. On the hypothesis of a once-continuous sheet of crush-conglomerate covering the area, these exposures may represent the infolded remnants of its plicated lower margin.

About a mile farther south a rim of breccia, as mentioned on a previous page (p. 48), borders the mass of grit on the moorland west of Glen Auldyn, and is prolonged north-eastward into the side-ravine south of Skyhill Farm, where it is traversed by several

'greenstone' dykes. Its course then becomes obscure through lack of exposures, but it probably reaches into the main glen a little farther northward.

On the eastern side of Glen Auldyn the autoclastic condition is imperfectly developed in the low crag overlooking Balleigheragh; and occurs, in a series of streaks a few feet wide, in the stream-bed of the deep glen falling into Glen Auldyn on the east, near the old lead mine marked on the Ordnance map. These streaks probably represent the westerly point of a wedge expanding rapidly north-eastward in the direction of Ramsey, but for three-quarters of a mile cultivated ground intervenes, and there are no outcrops. A belt of breccia having a breadth of about 300 feet is then revealed in Ballacowle or "Elfin" Glen (unnamed on the map) on the southern outskirts of Ramsey, and is prolonged thence towards the sea in the broad ridge of Ballastowell. Its major portion is then lost, within 150 yards of the coast line, under a low terrace of drift; but its southern margin reaches into Ballure Glen, and may possibly be continuous with a narrow strip, twenty or thirty feet wide, which is visible in a little headland of the adjacent coast, 150 yards east of the first cliff of the solid rocks. This strip appears to be wedged in between parallel faults.

In the eastern portion of the Ballastowell ridge the conglomeratic belt is over 200 yards wide, and its depth, between the lowest and highest visible points, about 300 feet. Where cut by the new mountain-road in the craggy slope overlooking Ramsey, its northern margin appears to be faulted; but the same margin to the westward of the Albert Tower, 250 yards farther west, shows a gradual passage from a coarse breccia of grit- and flag-fragments in a slaty matrix, to sandy and slaty flags in which the bedding, though much shattered, is more or less continuous.

In two places on the ridge, the breccia has been quarried for building; the more extensive excavation is at the eastern base of the hill, behind Ballure House; and the smaller, near the summit at the western end, close to the farmstead of Ballastowell. From the talus of the latter quarry Mr. Bolton, as already mentioned, obtained the supposed impression of a trilobite. The specimen is discussed on a subsequent page (see p. 93).

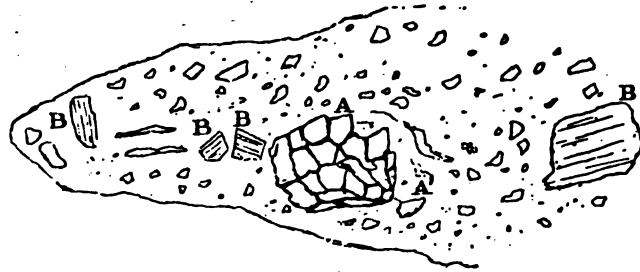
The district to the westward of Sulby Glen now remains to be described. While partial brecciation is of frequent occurrence in this area, the complete disruption of the bedding is, with certain notable exceptions, rarely attained. A few limited strips of crush conglomerate have been recognized in the 'unseparated' tract to the westward of the outer belt of Barrule Slate, but it is uncertain whether they occur independently, or represent a definite plane. Thus, on the hill-slope east of Kirk Michael the structure, in a slaty form, is scantily exposed near the margin of the gritty flags of that district. Similar material is seen again near Chester, two miles S.S.W. of the former locality, in a low outcrop between the forks of the small streams which unite at this place. At Corvalley rather over a mile farther along the

same line of strike, a better exposure of highly sheared slaty conglomerate was observed in a small field-quarry 200 yards west of the high road and 500 yards S.W. of the ancient chapel ruins (Keeill Pharick).

It is on the coast, however, about a mile to the westward of these places that we find the best of the western outcrops, in the cliff-section noticed by Henslow (see p. 55). This is, indeed, the only large-scale exposure of the structure to be found on the shores of the Island, and though somewhat inaccessible, it is fortunately in other respects excellent. From the northern end of the section at Gob ny Creggan Glassey near where the solid rocks first rise into the cliff, we may find here and there for a mile to the southward, thin streaks of breccia upon definite

FIG. 12.—*Plan of Crush-conglomerate in floor of a cave south of Gob y Deigan, showing breaking-up of flaggy inclusions.*

Area, about 9 square feet.



A. Portion of a flaggy band with deep cracks filled with the blue slaty matrix.

A'. Fragment just separated from A.

B. Blocks of flaggy slate showing remains of original bedding.

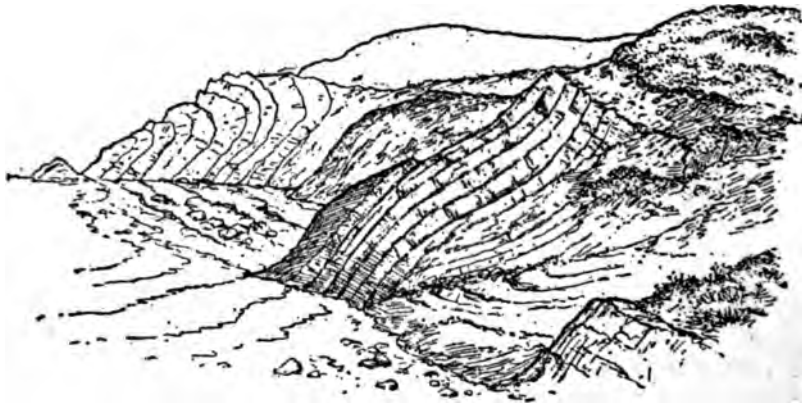
shear-planes bordering the thin grit bands which occur among confused and crumpled banded slates; (see Fig. 33, p. 122). But when we pass beyond Gob y Deigan, to the point where the buttresses of the cliff are perforated by a series of picturesque sea-worn caves and arches¹ (probably betokening lines of fault), we suddenly find that the whole section, from low water mark on the foreshore to the crest of the solid cliff 60 to 80 feet high, is composed of autoclastic breccia in various stages of disruption. From this spot up to the northern edge of the supposed outlier of the Niarbyl Flags (p. 38) at Ballanayre Strand, 350 yards distant, we have a succession of similar exposures, differing only in the degree of the brecciation and the size of the unbroken intercalations. Access to the section is somewhat

¹ This charming spot is now locally known as Gob y Deigan (Devil's Gob), but the Gob y Deigan of the Ordnance map is the little headland 500 yards farther north.

difficult, not only from the ruggedness of the cliff and shore, but also because the exposures can only be reached at low water of spring tides and the time during which they can be studied is therefore limited. The difference between the aspect of the breccia in surfaces subaerially weathered and in those seaworn, as noted by Henslow, is very striking; in the former the fragmental character is blurred by the slaty cleavage and can scarcely be detected; while in the latter every feature is brought out beautifully, and every stage in the bursting asunder and dispersal of the harder fragments in the slaty matrix can be followed (see Fig. 12). Some of the more argillaceous fragments seem to have possessed a slaty cleavage before they were incorporated in the breccia.

FIG. 13.—*Folded flags at margin of Crush-conglomerate at Ballanayre Strand. Cliff capped by glacial drift.*

Height about 60 feet.



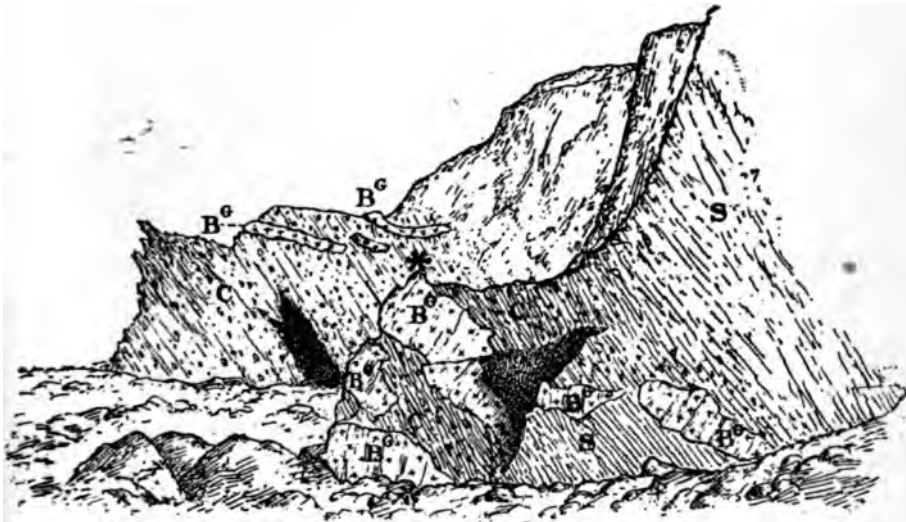
In the southern part of the section the conglomerate is traversed, as shown in Fig. 14, by several 'greenstone' dykes, some of which have been folded, frayed at the edges, and dislocated into long tapering segments by post-brecciation shearing, so that in the thinner examples their igneous structure has been almost obliterated. In spite of the number and variety of the Pre-Carboniferous intrusions of the Many Slates, all seem to be of later date than the brecciation. Careful search was made in many different exposures of crush-conglomerate for fragments of igneous rock among the other inclusions, but none was found, either in the field or by microscopic investigation (see p. 100). It is therefore clear that the movements by which these dykes were sheared and distorted, like those which produced the fissile cleavage in the breccia, were distinct from and later than the movements which produced the autoclastic structure. The quartz veins, also, with which the crush-conglomerate is frequently pene-

trated, present in this respect exactly analogous phenomena to the dykes. They have been stretched and broken, and the rock around them has been bruised and crushed, but they have not contributed fragments to the breccia.

The hard flags at Ballanayre Strand probably represent part of the nether millstone upon which the brecciation was accomplished, while at the same time their margin has not entirely escaped the process of disruption. The cliff-section in these flags (Fig 13) exhibits a good example of an overturned closed fold partly removed by erosion.

FIG. 14.—*Coast on northern side of Gob y Skeddan, showing broken and folded greenstone dykes traversing dark slate and Crush-conglomerate.*

Height of undercliff at * = about 40 feet.



S. Dark slate, greatly sheared, but still occasionally showing traces of bedding. Quartz veins abundant.

C. Crush-conglomerate.

B^G. Palish 'greenstone' dykes; the upper and lower bands of B^G in the foreground unite on the farther side of the nearer headland.

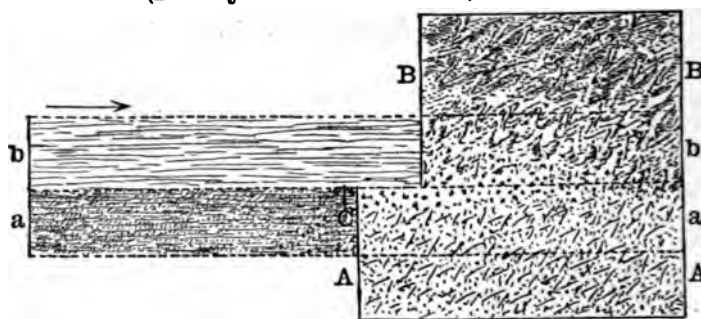
On the southern side of the same little bay the crush-breccia is again seen, in the form of a wedge, sharply bounded by unbroken beds, as if faulted in. Three hundred yards farther southward, near Gob y Skeddan,¹ both the foreshore and cliff are occupied by similar breccia, traversed by several much-disturbed dykes and confused by thrust-planes and faults, affording exposures scarcely inferior in interest to these previously described.

¹ This place is named on the six-inch Ordnance map, but not on the one-inch map.

Throughout the sections to the southward of the above, up to the incoming of the Peel Sandstone, the Slate Series with its accompanying dykes and bosses of greenstone is chopped up in every direction by thrust-planes and faults. Some of these may indicate displacements of large amount, like the boundary-fault of the Sandstone, but as their value could not be ascertained they have not been shown on the one-inch map.

FIG. 15. *Diagram to illustrate the production of crush-conglomerate where strong lateral pressure has affected a rock-system constituted of strata of different resistant qualities (compare Fig. 7, p. 61).*

(From Quart. Journ. Geol. Soc., vol. li.).



b—b (between dotted lines). Original position of argillaceous beds passing gradually downwards into a—a.

a—a (between dotted lines). Original position of sandy beds.

B—B. Argillaceous beds (slates) after compression.

A—A. Sandy beds (flaggy grits) after compression.

C. Zone of shearing and brecciation due to re-adjustment between B and A.

The strata are supposed to have been driven in from the side indicated by the horizontal arrow, which marks the direction of movement.

In concluding these descriptions it is essential to point out that in almost every case the autoclastic structure occurs where strata of different characters are in juxtaposition, and that the disruption has taken place chiefly among the passage beds between these dissimilar masses.¹ It has already been shown that the most probable interpretation of the stratigraphy of the Manx Slate Series as a whole is, that there has originally been an underlying platform of flags and grits (Lonan and Niarbyl Flags and Agneash Grits) passing up gradually, through rocks of intermediate type, into an overlying argillaceous mass (Barrule Slates), and that the whole group has undergone intense deformation. Under these conditions, differential movement on a large scale was most likely to occur in the intermediate zone, as the result of the difference between the compressibility of the underlying

¹ cf. Quart. Journ. Geol. Soc., vol. li., pp. 582-3.

and overlying rocks. Under powerful lateral thrusting, if the slates were driven into narrower bounds than the grits a local rending asunder and shearing of the interlocked masses one over the other would be produced. If the limits of the different rock-types had been sharply defined, the readjustment might have taken the form of a simple thrust-plane, but since the change of character was gradual, the disruptive effect, having no guiding plane, appears to have spread throughout the belt of passage-beds, shattering and milling many parts of them into dynamic breccia. Hence we find the crush-conglomerate to be fairly well restricted to a definite zone in the series, below the Barrule Slates and above the Flags and Grits. The diagram on the opposite page illustrates the production of the brecciated structure under the above-supposed conditions.

The results of the petrographical examination of the crush-conglomerate by Prof. Watts are given on pp. 100-106. They support and extend the conclusions drawn from the study of the rocks in the field, and furthermore show that the brecciation has not been accompanied by any increase in the degree of mineral alteration, the sediments possessing the autoclastic structure being not more altered than those in which the bedding is preserved. In an irregular belt along the structural axis of the massif, slates similar in composition to those involved in the brecciation have undergone a considerably higher degree of metamorphism, apparently from dynamic action, without disruption of their bedding (see p. 108).

Succession of Movements in the Manx Slates.

The earth-movements, as we have already seen, have affected the rocks at more than one period, and there seems to be strong grounds for believing that intervals of quiescence or comparative quiescence, perhaps of long duration, have separated the successive periods of movement. But as the effects of the different epochs have been superimposed one upon the other, the task of tracing out the successive stages is extremely difficult. In investigating the phenomena it has seemed to me that I could recognise the following phases; and this, though stated without much confidence, may serve, at any rate, as a provisional classification.

1. Consolidation of the sediments, accompanied by feeble disturbance of the bedding.
2. Acute folding, leading to fluxion-movement along the bedding planes, and in its later stages to extensive displacement in every part of the series, with the development of strain-slip and brecciation in certain areas.
3. Relief from extreme strain, and intrusion of the older basic dykes, and segregation of the older quartz veins.
4. Renewed pressure on the folded mass, causing the local development of close-set planes of fissility or shear-cleavage

through the further compression of the rock-material. Sericitic mica frequently developed on the planes of movement, along with other and more considerable metamorphic effects in certain tracts. The intrusion of the granitic rocks seems to have taken place at about the close of this stage.

5. After short interval of comparative quiescence, the stresses again renewed, especially on the flanks of the Island, acting in the same direction as before, but with less intensity, producing incipient cleavage in the finer grained strata, but with little shearing except along definite planes of weakness. The granitic dyke-rocks suffered deformation during this stage.

The above stages of movement seem all to have been Pre-Carboniferous.

6. Post-Lower-Carboniferous disturbances, producing much local complication in the Carboniferous rocks (see Chap. v.), but with no recognisable effect except normal faulting in the older strata.

Of these stages the second and fourth are those which principally concern us in considering the rock-structures, the former being especially the period of intense deformation and the latter of mineral alteration.

Other Effects of Movement in the Manx Slates.

While the crush-conglomerate represents an extreme phase in the effect of the orogenic forces, many other structures, falling short of this extreme but equally deserving our attention, have been produced by the same cause, and these will now be considered.

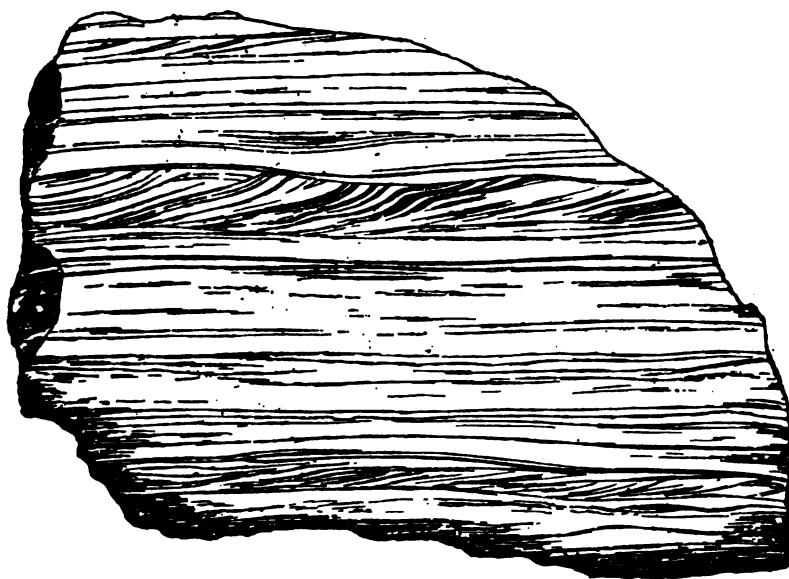
The flow of the rock-particles during the folding, in a direction more or less parallel to the bedding planes, has given rise to certain features which are best illustrated in the banded slates of the 'unseparated' type and in the finer-grained greywackes or mudstones of the Lonan and Niarbyl Flags. The dominant parallel planes in these rocks correspond generally to the original bedding, but here and there between these planes we may discern irregularities of the stratification, revealed by the colour-stripe, in the form of minute puckering and thickening of certain laminae, counter-balanced by the cutting out or tapering away of others, the structure sometimes simulating cross-bedding (see Fig. 16) and ripple-marking. It is by this kind of re-adjustment that the band as a whole has adapted itself to its position in the fold, thickening or thinning to a remarkable extent within the distance of a few feet.

Where the separate strata are thick, flaggy and nearly homogeneous, the intramural movement may implicate every particle of the individual band without disturbing the surface of the layers or destroying the general parallelism of the bedding. Where, however, the rock is thinly bedded, and especially where there are alternating layers of different composition, the same process has caused more or less disturbance of the bedding

planes, producing in one place crumpling through compression and in another disruption through stretching, with many curious modifications of form. These structures are frequently conspicuous on the surfaces of the flaggy beds, and, in the Isle of Man as well as in many other places,¹ have been mistaken for original characters of the sediments. The misapprehension has been particularly prevalent in regard to the minor plications of the bedding-planes, which have been

FIG. 16. *Laminated slate with disturbed bedding simulating cross-bedding. From a specimen in the Survey Collection obtained near Ramsey.*

About two-thirds natural size.



many times described as ripple-markings and held to indicate the shallow-water origin of the deposits. In every instance which I have examined, these supposed ripple-marks have proved to be secondary structures, due either to the emergence of parallel series of small step-faults akin to strain-slip (as in Fig. 17), or to the rucking up of the bedding plane in little folds which have sometimes been overthrown and broken in the under limb (as in Fig. 18).

¹ As for example, in the Cambrian Flags of Bray Head in Ireland, where, in all the cases I have examined, the so-called ripple-marks are identical in origin with those of the Isle of Man.

FIG. 17. *Section in crag on western side of Sulby Glen, west of bench-mark 137' 6" (six-inch map, sheet 4), showing method of production of pseudo-ripple marking by strain-slip-faulting.*

(From Quart. Journ. Geol. Soc., vol. li. Compare Fig. 18.)

Length, about 2 feet.



A A A. Bands of grit 1 to 3 inches thick, cut displaced and lengthened by (y—y) oblique strain-slip planes. Dark slate, much sheared, between the grit-bands.

This pseudo-ripple-marking is commonly developed in the thin sandy bands among the striped slates, but may occur in any hard seam traversing softer beds. Thus, the example represented in Fig. 19 shows the structure, on a small scale, in a thin segregation-vein of quartz.

Hence, although the rocks are in many places of a character in which ripple-marking may once have existed, it is doubtful whether

FIG. 18. *Rock-rippling of thin gritty layer in slate by earth-movement. From a specimen in the Survey Collection obtained on the foreshore at Cass-ny-hawin.*

About half the natural size.



the true structure anywhere now remains in them; if originally present, it has been masked by the secondary deformation.

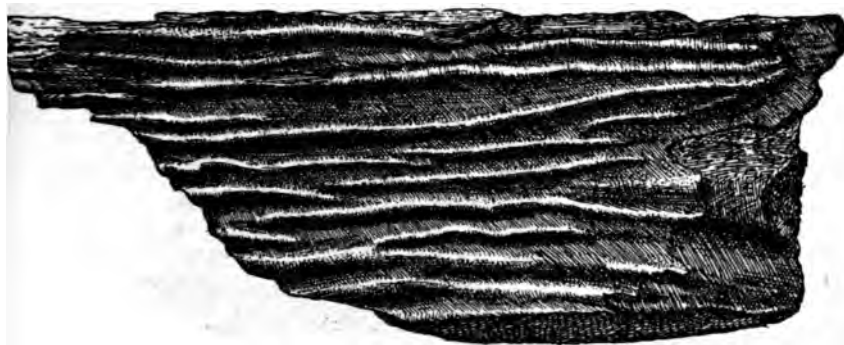
Analogous to the pseudo-rippling, but of rarer occurrence, is

another curious structure which is probably confined to the interior portion of the crests and troughs of closed folds. In such situations the harder rock-bands have sometimes been crumpled and thickened so that their surfaces have risen up into the more plastic material overlying them in small lenticular swellings or bosses, more or less regular in size and so arranged between two intersecting sets of strain-slip faults or joint planes that the rock-surface presents a rude embossed pattern.

This structure seems to have been noticed by Berger¹, who remarked that it was called by the quarry-men "knobby-side." An unusual example from the neighbourhood of Perwick near

FIG. 19. *Rock-rippling affecting thin quartz vein in slate. From a specimen in the Surrey Collection obtained on the slope beneath Gob y Volley.*

Slightly reduced.



Port St. Mary, in which the protuberances have been elongated, perhaps by a later movement than that which originated them is illustrated, though somewhat crudely, in Fig 20 on the next page, taken from my note-book.

Somewhat analogous to this structure and to a certain extent its reverse, produced probably under conditions of stretching instead of compression, is the singular tessellation sometimes exhibited by surfaces of thin beds in the flags due to a slight ridging up of the material along intersecting lines of jointing or strain-slip. These ridges, one-tenth to one-quarter of an inch high, form sets of fairly regular parallel lines, from one to three inches apart, crossing each other at uniform angles. Usually there are two sets of the ridges, as in Fig. 21, but occasionally three or more sets occur, resulting in a somewhat irregular meshwork of intersecting lines, as in Fig. 22. These structures evidently belong to the period of acute folding (No. 2 of the above classification), and they are crossed by the faint striæ of the later shear-cleavage (No. 4 and possibly in part No. 5 of classification).

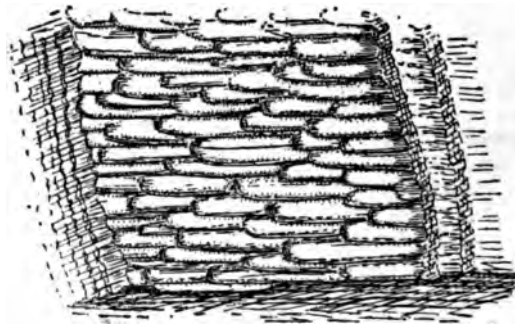
¹ Berger *op. cit.* p. 38. This structure also is beautifully developed at Bray Head.

Another interesting structure due to the differential movement of one bed over another during the folding takes the form of brightly burnished planes of stratification, which occur, though somewhat rarely, among the fine-grained Niarbyl Flags. Similar polished planes are well known in the folded limestones of the Jura.

It is evident that all these structures are early phases of the process which produced the brecciation, the difference being one of degree only. On theoretical grounds it has been stated that the 'zone of flowage' of rocks in the earth's crust lies below the

FIG. 20. *Corrugated surface of grit-band in flaggy slate, in west bank of gully south-west of Fistard village near Port St. Mary.*

Dimensions, 12 inches by 8 inches; the finger-like ridges are from $\frac{1}{2}$ to $1\frac{1}{2}$ inches broad.



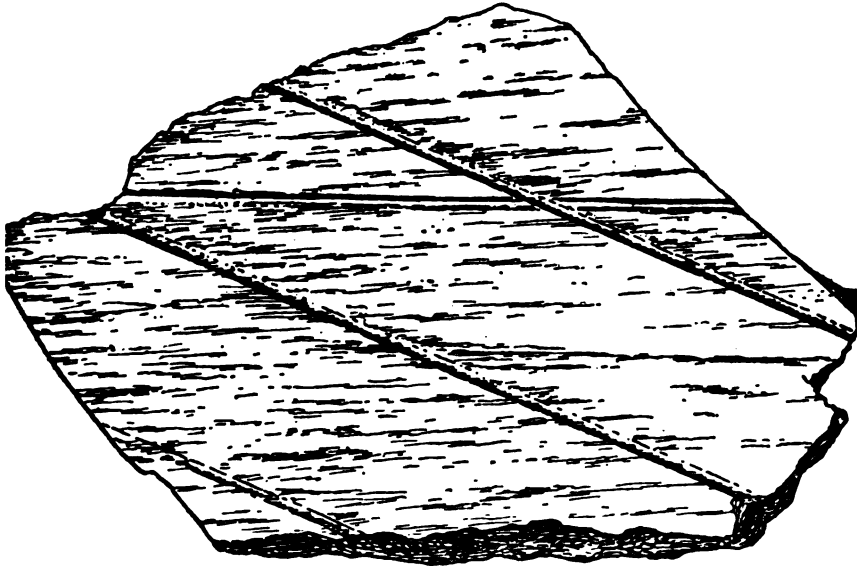
'zone of brecciation,' and that at a depth exceeding 10,000 metres no fracturing such as that indicated in the 'autoclastic' rocks can take place.¹ But while great depth may be requisite to bring the whole of a consolidated rock-mass into the state of flow, it is certain that very considerable transference of material by gradual "creep" from one part of the fold to another, can take place comparatively near the surface, even in rocks of extreme hardness. In the Isle of Man the brecciation does seem to have taken place at a slightly higher horizon than that occupied by the unbroken grits and flags, but I think it is by the dissimilarity in lithological composition of the rocks, and not by the relatively small difference in depth that the variation in the character of the secondary rock-structures can be most readily explained. During the production of a fold under a certain thickness of super-incumbent material, the stresses in one and the same place must vary greatly from time to time, according to the position which the moving strata assume in regard to the direction of the pressure, so that any particular segment

¹ See Van Hise, *op. cit.*, pp. 592 *et seq.*

during one part of the process might be placed under conditions producing 'flowage,' and at another under those producing fracture. In this connection the element of time, as it is acknowledged,¹ may be of prime importance, since extensive deformation by flow might take place under comparatively slight stress, if this be sustained sufficiently long. All the various above-described effects of movement in the Manx rocks may be explained by supposing that in some cases the compressive forces were so slow in their action as to permit gradual re-adjustment

FIG. 21. *Puckerings on bedding-plane of fine-grained flags (Niarbyl Flags); from specimen in the Surcey Collection obtained on the coast near Dalby Point.*

About one-third natural size.



of the material in the growing fold by "creep," while in other instances the 'natural plasticity' of the rock—if we may use this term—could not keep pace with the rate of growth of the fold, and more rapid methods of deformation were then called into play. Under the latter conditions the intersecting systems of strain-slip-planes with their concomitant phenomena have been produced, and these may be traced step by step, with increasing severity of displacement (see Figs 23 and 24), until we reach the extreme state of complete disruption of the strata and their reconstruction as an autoclastic conglomerate.

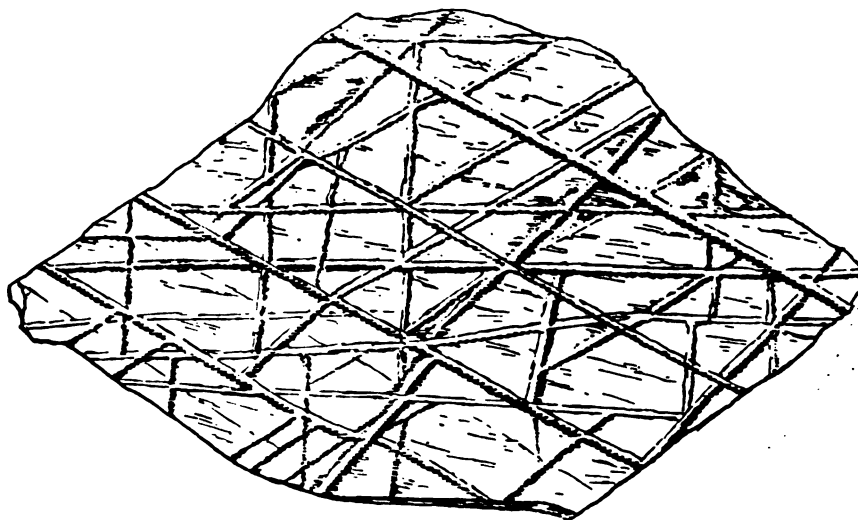
At a somewhat later date than the major folding, the

¹ See Van Hise, *op. cit.*, p. 594.

structure which I have described as 'shear-cleavage'¹ was extensively developed in the area. This structure, agreeing in most respects with that termed 'fissility' by some authors,² and 'ausweichungs-cleavage' or 'strain-slip cleavage' by others, consists in the development of close-set, more or less parallel planes of shearing, along which the opposing surfaces have been slightly shifted relatively to each other. A distinction is usually drawn on theoretical grounds between this structure and the 'true' or 'ultimate' slaty cleavage, in which the mineral particles of the cleaved rock are supposed to have been

FIG. 22. *Tessellated puckering on bedding-plane of Niarbyl Flags; from specimen in the Survey Collection obtained on the coast near Dalby Point.*

About one-third natural size.



forced by pressure into such a position that their longer axes possess a parallel arrangement throughout the mass, so that the tendency of the rock to split in a definite direction is not confined to particular planes, but affects equally every portion of the material. It is doubtful, however, whether this distinction can be made in the field in any area where extensive shearing has taken place, and where both structures may be present in the same rock. In the Manx Slates, though the 'shear-cleavage' is nearly always predominant, the two structures

¹ Quart. Journ. Geol. Soc., vol. li., p. 567. My reason for applying a separate term to this structure is, that it is frequently present along with a much more widely spaced and better-defined system of strain-slip planes independent in direction and apparently of older date, probably connected with the brecciation-stage of movement. See Figs. 17 and 24.

² See Van Hise, op. cit., p. 633.

appear to merge inseparably into each other, so that the interior portion of a block of slate surrounded by shear-planes may possess a structure indistinguishable from 'ultimate cleavage,' but passing insensibly at the margins into well-marked 'shear-cleavage' or 'fissility,' without change of direction.

The period at which this shear-cleavage was developed in

FIG. 23. *Crest of fold in Niarbyl Flags in cliff at northern side of The Ladder, Contrary Head.*

(From Quart. Journ. Geol. Soc., vol. li.).

Length, 4 feet.



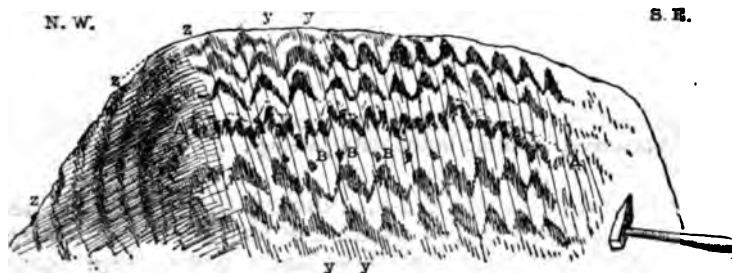
A, A. Pale band in slaty flags, pulled apart into pebble-like lenticles 1 to 2 inches in length.

y, y. Faintly-developed planes of strain-slip.

FIG. 24. *Crag of strongly-banded sandy slate in eastern bank of Sulby River below Snaefell, (450 yards north of "Lead-mine" of six-inch map, Sheet 7).*

(From Quart. Journ. Geol. Soc., vol. li.).

Length, about 5 feet.



A, A. Grit-band, about $\frac{1}{2}$ inch thick, crumpled and partially broken, among puckered slates.

B, B, B. Isolated pebble-like fragments of grit, apparently squeezed out from the band A.

y, y. Strain-slip planes, cutting and displacing the bedding.

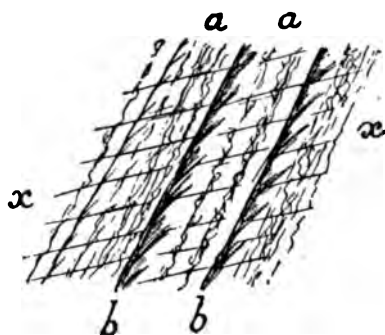
z, z. Later 'shear-cleavage,' with the same strike as the bedding (N. 40° W.) but a different degree of dip (about 30°).

the Manx rocks must have been later than their brecciation, since it has affected the crush-conglomerates equally with the surrounding unbrecciated rocks (see p. 62, Figs. 9, 10), and also the greenstone dykes, which, as we have seen (p. 68), were injected among the slates after the brecciation. These dykes

in many places have been shredded down into chloritic schists by the later shearing. During their intrusion the earth-movements seem to have relaxed in severity, or were even temporarily in abeyance, (Stage 3 of classification). Afterwards there came a renewal of the forces, acting in the same direction as before, still further compressing the already packed and folded massif, and producing a fissile structure both in the sediments and the dyke-rocks (Stage 4). Later followed the intrusion of the granite masses, with their associated micro-granite dykes, which are seen in many places (see pp. 128, 150) to intersect the older greenstones and to alter them at the contact in such a manner as to suggest that the basic dykes had previously received their 'shear-cleavage.' Whether there

FIG. 25. *Diagram of edges of pale flaggy mudstones (a, a) with thin dark blue slaty partings (b, b).*

Natural size.



x, x. Shear-cleavage, obscure in the mudstones, but strongly developed as an oblique serrated frilling in the slaty partings.

was any relaxation of the pressure during the irruption of the granites is not clear, but it is certain that the strain was renewed (Stage 5) after the consolidation of those rocks, since shear-structure has been imparted to their margins and to their elvans, though in a less degree than to the older basic dykes.

The quartz veins stand in the same relation to the different stages of movement as the dykes; they are all posterior to the primary folding and brecciation, but have been formed during more than one of the later stages, and some have therefore been implicated to a greater extent than others in the movements. A few of the veins seem to be of later date than the disturbances and are probably Post-Carboniferous, but these are comparatively rare.

In the strongly banded slates bordering the Barrule Slates, and in the argillaceous intercalations among the flaggy rocks

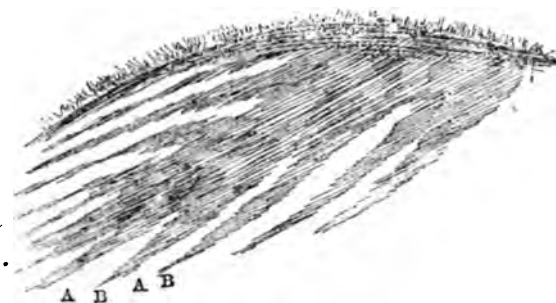
of the 'unseparated' central area, the shear-cleavage is especially well developed and frequently in more than one direction. On the flanks of the island it is not so well seen, except occasionally in the slaty intercalations of the Lonan and Niarbyl Flags.

The more or less oblique emergence of the shear-planes upon a rock-surface frequently produces a peculiar and characteristic minute frill-structure in beds of fine texture. This structure is most apparent in the argillaceous layers, and sometimes strips out thin slaty partings among the harder flags transversely along the strain-slip planes, so that each

FIG. 26. *Section in crag on western slope of Glen Dhoo, Ballaugh (opposite "T. Mill" of 6 inch map, Sheet 7), showing extreme shearing of strata in the crest of a fold.*

(From Quart. Journ. Geol. Soc., vol. li.)

Length, about 3 feet.



A, A, Sandy and B, B, slaty bands, fairly well defined in the limbs of the fold, but frayed out into reconstructed schistose material in the crest.

lamina presents a saw-like cross section bearing some resemblance to a sheared graptolite, as shown in Fig. 25.

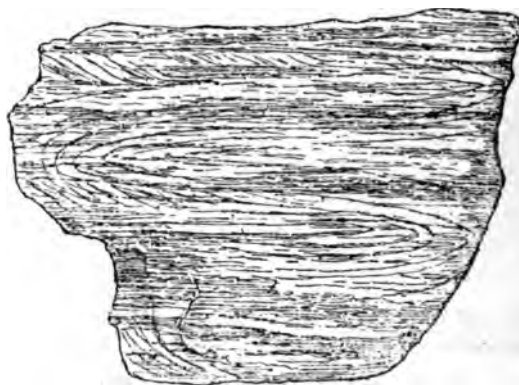
The frilling reaches its greatest intensity on the crests of folds, where it sometimes nearly obliterates even the most pronounced bedding (see Fig. 26), while in the more homogeneous strata like the Barrule Slates the structure completely overpowers the original stratification.

Frequently the parallel planes of fissility, when transverse to the bedding, are thickly clustered in bands of $\frac{1}{4}$ to $\frac{1}{2}$ inch in breadth, separated by intervening unaffected spaces of an inch or two; and in such cases the alternation of the sheared zones showing the sericitic shimmer with those in which the fissile structure is absent, gives an appearance very closely simulating true bedding, though of course in no way connected with it; as in Fig. 27. When sheared dyke-rocks are affected by this false stripe it is impossible to distinguish them from the slates, unless independent evidence can be obtained of their intrusive character.

The difficulty in distinguishing between the bedding and the 'fissile tendency' in such cases was commented on at considerable length by Macculloch, who failed to recognise the true character of the sheared 'greenstone' dykes, and was thereby led to the conclusion that these dykes in a section near Douglas were greywacke bands and indicated the true bedding planes.¹ Henslow was similarly misled by the resemblance of the dykes to greywackes²; as also, at much later dates, Harkness and Nicholson, by an altered trap at Laurel Mount near Ramsey,³ and Clifton Ward by the sheared microgranite at Crosby⁴ (see pp. 135, 168).

FIG. 27. *Belts of strain-slip traversing crumpled slate and producing an appearance resembling stratification. From specimen in the Survey Collection from the Barrule Slates near Snaefell.*

About half natural size.



In some localities, especially in the belt of laminated slates between the Agneash Grits and the Barrule Slates, the rocks possess two or even three distinct systems of cleavage-planes, striking in different directions and intersecting each other at definite angles, as shown in the annexed example, Fig. 28.

In such cases it is difficult to decide whether we are dealing with the effects of separate stages of movement superimposed upon each other; or with the complex results brought about during a single stage by the gradual change of position of the strata during the formation of the fold; or with instances of uncomplicated 'cross-fissility,' a structure thus described by

¹ "The Western Islands, etc.," pp. 542-544 and pl. xxviii. Fig. 1.

² Trans. Journ. Geol. Soc., vol. v., p. 490, and Pl. 35, Figs. 1, 2 and 3.

³ Quart. Journ. Geol. Soc., vol. xxii., p. 489.

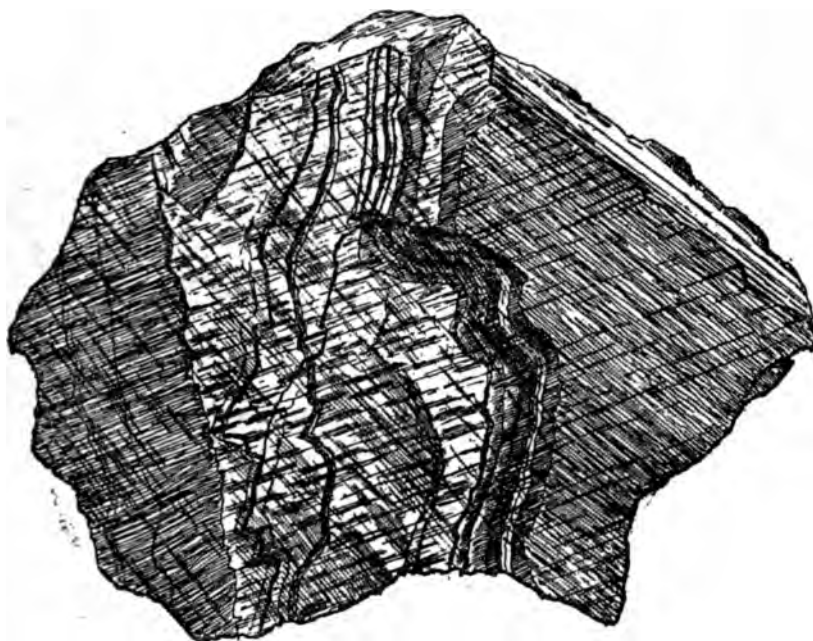
⁴ Geol. Mag., dec. ii., vol. vii., p. 3.

the American geologists¹:—"In the zone of fracture where the differential stress surpasses the ultimate strength of the rock, there may be produced a fissility in two sets of intersecting planes equally inclined to the greatest pressure."

If we accept the last explanation as the most probable, then we

FIG. 28. *Laminated slate with intersecting planes of shear-cleavage in three directions. From specimen in the Surrey Collection from margin of Barrule Slates south-east of Snaefell.*

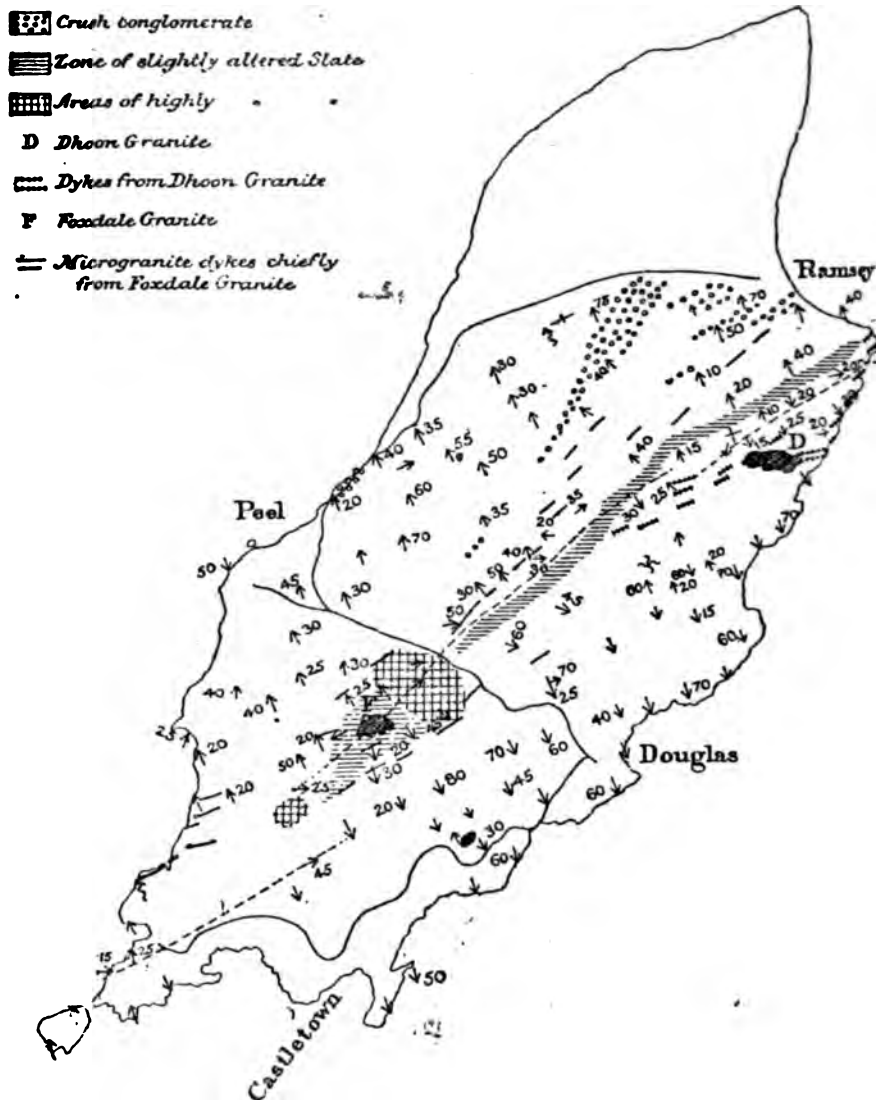
Nearly natural size.



shall recognize in the specimen figured above, (1) Flow-structure parallel to the bedding-planes, assignable to Stage 2 of our classification, and (2) 'cross fissility' of later date (Stage 4), in this case meeting at an angle of 80° , but in other places making angles varying from 35° to a right angle. In the central part of the massif, where the 'cross-fissility' is chiefly developed, these are perhaps the only stages of movement definitely recognizable in the sedimentary rocks, and evidence for the later stage (5 of classification) is presented only by the intrusive microgranites. On the flanks of the Island, however, the last-mentioned stage appears to have given rise to a 'later cleavage' in the slates, though as hinted above the distinction between it and the earlier

¹ See Hoskins and Van Hise, op. cit., pp. 64 et seq. and 845 et seq.
3194.

FIG. 29. *Sketch-map of the Isle of Man, showing (a) principal cleavage; (b) position of metamorphosed slates; (c) position of granitic intrusions and of dykes connected therewith; and (d) distribution of crush-conglomerate.*

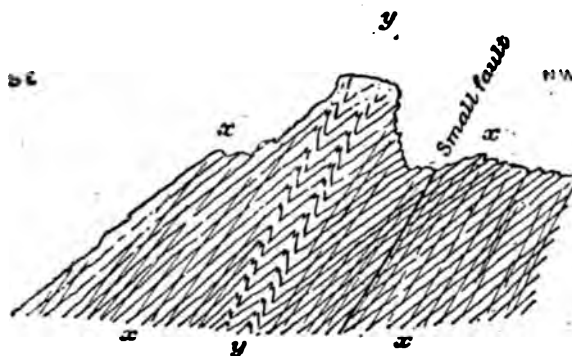


The arrows show the direction of dip of the dominant cleavage, and the figures the amount in degrees. The broken line indicates the position of the somewhat interrupted anticline of cleavage. The continuous lines mark the railways.

structures is often far from satisfactory. This latest cleavage affects the greenstones and microgranites equally with the stratified rocks. With few exceptions, it preserves a regular strike in every part of the Island where it can be recognized, and dips generally from the central anticlinal axis, as shown on the sketch map, Fig. 29. This regularity indicates that the strata had been folded and packed before this cleavage was developed in them and that they have not since been much disturbed. Even at this stage, some minor degree of shearing has taken place among the rocks, since the cleavage-structure only now and again approximates to 'true slaty cleavage,' and more often has the character of slight strain-slip. Its direction frequently coincides with that of the earlier structures, and where the angle of dip is also the same it is indistinguishable from them.

There is frequently a close relationship between the folding of the strata and the cleavage-structures, as shown in the following section, Fig. 30, where the inclined axial planes of the minor folds are parallel to the planes of the cleavage.

FIG. 30. *Section in Lonan Flags at foot of cliff on north side of the North Pier at Laxey, showing agreement between axial plane of folds and cleavage.*



x-x. Obscure cleavage in same direction as bedding but at a steeper angle.
y-y. Axial plane of small fold

It is also common to find the cleavage in agreement with the bedding planes of the strata both in strike and dip, in which case the secondary structure is only visible in weathered outcrops, where it will often cause the thicker rock-bands to shiver into slaty fragments. It is in the crests and troughs of folds, where the bedding diverges from the dominant direction, that the structure is most distinctly visible (see Figs. 3 & 26).

On the flanks of the Island, and in the flaggy rocks generally, the most frequent relationship is that while the bedding and

cleavage have approximately a common strike, they diverge widely in degree of dip, that of the cleavage remaining steady over wide areas, while that of the folded bedding varies from point to point. Even in the larger folds like the great syncline skirting the east coast from Clay Head southward to beyond Douglas Head, the cleavage is unaffected by the reversal of the bedding and maintains its dominant direction and angle across the strata.

This cleavage has an unfavourable effect upon the rock as a building-stone, its oblique emergence on the bedding-planes producing a wedge-shaped edge in the quarried flags which can be only partially removed by dressing.

The granitic bosses of Foxdale and the Dhoon appear to cause a displacement of the anticlinal axis of cleavage in their vicinity, as elsewhere described (p. 168), as well as some minor local modifications (see Map. Fig. 29). But the intrusions occur in the belt in which the different structures are more or less inseparable; and while the evidence suggests that a fissile structure was in existence in the strata before the irruption of the igneous rocks, and that other structures have been imparted since the consolidation of the granite, it is not sufficient to enable us clearly to distinguish them where both are present.

Faults.

As already mentioned, the value and effect of overthrusts and faults upon the Manx Slate Series can rarely be estimated although we know that extensive displacements have occurred both in Pre-Carboniferous and in Post-Carboniferous times. Even the faults which bring down the newer Palæozoic strata into the flanks of the massif can rarely be traced beyond the borders of the Carboniferous rocks, from the difficulty in identifying them amid the general confusion and deformation of the older strata and from the prevalence of fault-like effects produced by other causes. For example, the disappearance of members of the Slate Series on their line of strike may be either the result of faulting or of the pitch of the folds; and a sudden change of rock-character at the surface transverse to the strike, when the strata are so often almost vertical, may denote a strike-fault or simply the upturned normal succession of beds of different composition. For these reasons the tracing of fault-lines within the Manx Slate area must necessarily be more or less hypothetical; and it was thought inadvisable, so long as the difficulties of the ground could be otherwise explained, to introduce such lines on the published map.

Nevertheless, the cliff-sections all round the shores of the Island reveal planes of crushing and probable dislocation at frequent intervals, and similar appearances are numerous in the stream-beds of the interior, giving rise to deep narrow rock-gullies where they coincide with the water-courses, and to

cascades where they cross them.¹ Most of these fractures fall into one or the other of two sets, going either about E.N.E. to W.S.W., *i.e.*, approximately with the strike of the rocks; or in a direction more or less nearly at right angles to this, namely, N. or N.W. to S. or S.E., *i.e.*, across the strike.

The planes of the strike-faults are sometimes of low hade and accompanied by crushed stringers of vein-quartz and brecciated rock, with other indications of reversed faulting or overthrusting (see Fig. 44, p. 178); while the north and south fractures are generally steep, sharply defined, with a newer aspect, and like normal faults. On this evidence it was at first thought that all of the former set were older than all of the latter; but an examination of the north and south lodes of the lead mines at Cornah, Laxey and Ballacorkish (see p. 487), which seemingly represent faults of this direction, revealed the fact that these are intersected and displaced by 'slides' or faults having the east and west direction. Hence it appears likely that each set may include fractures of different epochs.

That some of the faults may be of Post-Triassic age is indicated by the presence of a dislocation in one of the deep borings in the north of the Island, which apparently brought down the Triassic rocks against Carboniferous Limestone (see p. 283). In Cumberland, in the district adjacent to the coast, where the geological structure is closely related to that of the northern part of the Isle of Man, there are, besides the Pre-Carboniferous fault-systems about which little is known, at least two later systems, one Pre- and the other Post-Triassic, the older set, striking N.E. to S.W., affecting only the Carboniferous rocks, and the newer set, striking N.W. to S.E., dislocating the Trias and Permian along with the Carboniferous.² It is very probable that the same conditions extend to the Island, where, however, as the Triassic rocks are concealed by drift we are unable to establish the point.

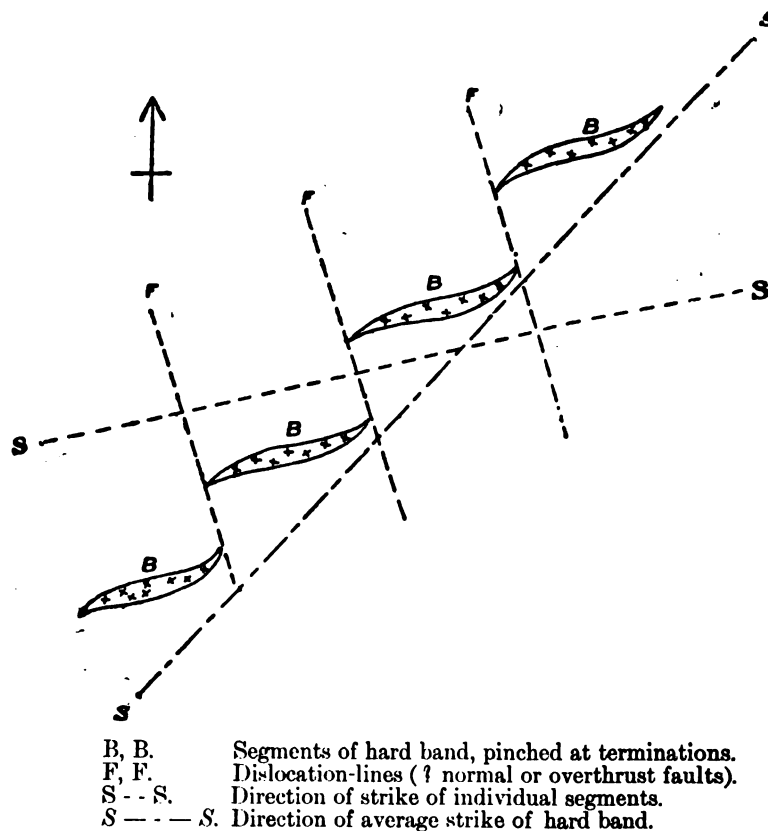
The high angle at which the Manx Slates are usually inclined would allow considerable vertical displacement of the opposite sides of a fracture without much apparent effect on the outcrop; and it is possible that the contraction and expansion exhibited by rock-belts in some parts of the massif, as shown on the map, may be due to systems of faulting transverse to the folds. At the same time, the general persistence of these belts seems to imply that no individual fault can be very great. Excepting in the case of the Niarbyl overthrust (p. 148), the boundaries of the different divisions of the Series, where exposed in the cliffs, do not definitely indicate faulting; and the changes of rock-character which are sometimes visible on the opposite sides of fractures are usually such as to imply that the beds brought into contact were originally not very far apart.

¹ Many of these fractures of unknown value have been recorded on the MS. clean copies of the six-inch sheets which have been deposited in the London office of the Survey.

² These two systems are brought out clearly by the mapping (see one-inch map, Sheet 101 S.W.)

It appears probable that the master-faults of the Island are those on the edges of the old massif, and that, indeed, their occurrence has determined its position. Thus the downthrowing of the Carboniferous Limestones on the south-eastern flank of the Island; of the Peel Sandstone on the west; and probably of the Permian-Triassic and Carboniferous rocks on the north has defined the extent of the higher central mass of the Slates. Even these displacements need not be of more than moderate magnitude; that which bounds the Carboniferous basin of the south is not large, in spite of its important effect upon the stratigraphy (see p. 196), while those which bring in the Peel Sandstones, though of higher value, can only doubtfully be traced into the interior, and certainly do not seriously break the westerly belt of Barrule Slate.

FIG. 31.—*Diagram (plan) to illustrate common structure in hard bands, whether dykes or layers of grit, in Manx Slates; showing divergence between strike of segments and strike of band as a whole.*



The peculiar dislocation and displacement in short segments of the quartzite-bands and many of the dyke-rocks, especially

the microgranites, described in other parts of this work (pp. 137, 182 and pp. 128, 167), are probably due to the development of step-faulting in a manner not yet understood. This structure is admirably displayed by the microgranite dykes which pass from the south-western coast near Fleshwick inland towards the Foxdale Granite; and again by those of the north-eastern coast around Maughold Head which are connected with the Dhoon Granite. These are apparently cut into segments and displaced along more or less vertical planes which have a general, though not universal, tendency to shift the separated portions, bit by bit, in one direction, the Foxdale dykes being dragged to the northward of their easterly course and the Dhoon dykes to the southward of their westerly course (see map, Fig. 29, p. 84). Similar peculiarities may be observed in the thicker bands of quartzite, in the coast-sections between Cass ny Hawin and St. Anne's Head, as well as in other places.

It is very probable that the same structure may be accountable for that divergence from the apparent strike already mentioned as characteristic of the general arrangement of the Manx Slates, and especially of their flaggy and gritty divisions. It seems to imply some system of 'step-faulting' by which the massif has been cut up into strips which have been laterally displaced, in a definite direction relatively to each other, as in Fig. 31. The subject is one which might well repay further investigation.

These features and others in regard to the position and relations of the larger igneous intrusions seem to indicate the presence of a multitude of small overthrust and normal faults, which, in the aggregate, may have had considerable effect. It is more than probable that I have myself failed to make sufficient allowance for both kinds of faulting; it must be left to the future worker to discriminate more closely between the relative values of folding and faulting in the production of the intricate structure of the Manx Slates.

Paleontology of the Manx Slates.

Almost the only traces of organisms in the Manx Slate Series are the tubular 'worm-casts,' which are fairly abundant in some localities on the surfaces of the flaggy beds, especially where the rocks consist of thin alternations of argillaceous and fine arenaceous material. The presence of these markings in the slates was first mentioned by Cumming and afterwards by Harkness and Nicholson, Binney and others. Recently the whole subject has been reinvestigated by Mr. H. Bolton, whose descriptions are quoted below. Mr. Bolton's personal researches have also brought to light specimens which he believes to represent the cast of a trilobite and two examples of graptolites. But the conditions under which these specimens occurred seem to justify some doubt as to their character, especially since some examples of markings collected during the course of the survey, which were thought to indicate

organic remains of the same kind, have proved under microscopic examination to be of inorganic origin. This subject will be further referred to after the descriptions of the specimens have been quoted.

In his recent paper¹ Mr. Bolton has critically discussed the previous palæontological literature, and in the following passages he sums up the work of his predecessors and the result of his own researches.

"In 1862 Mr. J. [E.] Taylor² described certain supposed imprints in the slates of Dalby. These imprints were said to resemble the dotted outline of the *Protichnites* figured in Owen's *Palæontology*.

"Mr. Mackie, Editor of the *Geologist*, thought that the impressions looked more like portions of gigantic *Lingulæ* or some fibrous shell. Mr. Salter denied their organic origin altogether, and Mr. Lamplugh informs me that the impressions were probably the hollows left by the decay of the slightly calcareous nodules, which occur rather abundantly in some localities.

"In 1863, a paper was read by Mr. Taylor³ before the Manchester Geological Society, in which he mentioned the discovery by Mr. Thos. Grindley of a fucoid, and also avers that behind the Castle Mona Hotel he himself discovered both fucoids and the tracks and castings of worms.

"At Mount Craig he found the remnant of an *Orthoceras*, the specimen showing the chambers and also the gradual tapering of the body of the shell.

"In the absence of either the specimen or of any figure, neither of which seem to have been exhibited, very little reliance can be placed upon the description.

"It is not unlikely that it refers to some partially weathered-out worm-casting, or to thin intersecting mineral veins, which in these rocks often simulate chambered organisms.

"Profs. Harkness and Nicholson⁴ in 1866 recorded the finding of *Palæochorda major*. Mr. E. W. Binney⁵ next took up the work in 1877, and published figures and descriptions of worm-tracks which he named *Nemerites monensis* and *Neretites monensis* respectively. Worm-burrows (*Scolites*) were also mentioned, and certain oval structures which he supposed had some faint resemblance to *Lingulæ*, but which Mr. Lamplugh thinks may have been the cross-sections of worm-casts.

"Whatever these latter may have been, one was somewhat doubtfully referred by Binney to *Lingulella davisii*.

"In the succeeding year Binney⁶ figured and described the supposed fucoid found in the glacial drift at Laxey, and from a superficial resemblance of the specimen to *Psilophyton cornutum* of Lesquereux, he was led to name it *Psilophyton monense*. In a later communication, Binney⁷ states that Dr. Dawson was of opinion that the supposed plant more

¹ "Palæontology of the Manx Slates," Manchester Memoirs, vol. xliii. (1899), no. 1., pp. 1-15, with a plate.

² "Supposed Imprints in the Lower Cambrian Beds of the Isle of Man." *Geologist*, vol. v., 1862, p. 321.

³ "Cambrian Strata of the Isle of Man." *Trans. Manch. Geol. Soc.*, vol. iv., 1863, p. 285.

⁴ "The Lower Silurian Rocks of the Isle of Man." *Quart. Journ. Geol. Soc.*, vol. xxii., 1866.

⁵ "A Notice of some Organic Remains from the Schists of the Isle of Man." *Proc. Manch. Lit. and Phil. Soc.*, vol. xvi., 1878, p. 102.

⁶ "Notice of a Fossil Plant found at Laxey, in the Isle of Man." *Proc. Manch. Lit. and Phil. Soc.*, vol. xvii., 1878, p. 85, and *Manch. Memoirs*, 3rd Series, vol. vi., 1879, p. 214.

⁷ "Remarks on a Fossil Plant found at Laxey, in the Isle of Man." *Proc. Manch. Lit. and Phil. Soc.*, vol. xviii., 1879, p. 19.

nearly resembled *Buthotrephis harknessi* of Nicholson; it is well to bear in mind, however, that Dr. Dawson was guided in his determination by the description and figure, and not by an examination of the specimen.

"Prolonged research amongst the slates by many recent workers has revealed no trace of true fucoids, and, as we shall see later, the supposed fucoids were, in all probability, the casts and tracks of *Palæochorda*. In the absence of descriptions, figures or specimens, we are forced to reject the supposed fucoidal structures of Taylor, Grindley and others.

"*Psilophyton monense* of Binney calls for more attention. It was described as follows: 'The stem is thick, dichotomous, divisions variable in distance, the terminal ones short, pointed, nearly equal in size and length, surface nearly smooth. The branches in the lower part are thick comparatively to their length. The surface of the stem appears to be smooth, and affords no evidence of striæ or scales.' A woodcut accompanies the description, but is too coarsely drawn to illustrate anything except that there is no dichotomy.

"The specimen was said to run nearly at right angles to the bedding (cleavage), and that it lay upon the surface of a boulder taken from the glacial drift.

"In this case, as with previous writers, there is a lack of positive evidence, but an attempt has at least been made to describe the supposed fucoid intelligently. It is most unfortunate that the woodcut does not increase, but rather nullifies, the value of the description.

"The species cannot be accepted as a good one, nor is there evidence to show that the boulder was derived from the slates of the island. There is no certain knowledge of plant remains.

"Animal remains are of a less uncertain character than the fucoids, but are few in number and species, and far from satisfactory.

"Worm-castings, tracks and burrows.

"Under this head must be placed the *Palæochorda major* and *P. minor*, McCoy, once regarded as fucoids.

"*Palæochorda major* was recognised in the Manx slates by Profs. Harkness and Nicholson, and considered by them of considerable value in correlating the latter with the Skiddaw slates of the Lake district. . . .

"Worm-castings, tracks and burrows are fairly common in many of the Manx slates, and certain grits are almost composed of them. Especially is this the case in the cliffs south of Port[h] Mooar.

"*Palæochorda minor*, McCoy.

"The smallest worm-castings the writer has seen are a series collected by Mr. G. W. Lamplugh. . . .

"The castings are usually in the form of long straight semi-cylindrical rods, rarely occurring in clusters, or showing much trace of coiling. They consist of grains of sand hardened into a fine grit.

"To this species we would also refer Mr. Binney's *Nemerites monensis*. The latter was stated to occur in blue laminated slate at Oakhill, Braddan, and was found during the cutting of the railway from Douglas to Castle-town. It was described as occurring in the form of a simple loop, twelve inches long and one-eighth of an inch in diameter. Mr. Binney's figure agrees very closely with that of *P. minor* figured by McCoy.

"*Palæochorda major*, McCoy.

"Worm-castings, larger than those of *P. minor*, occur abundantly in many of the slaty grits; they vary somewhat in diameter, from three to four lines being a fair average. Not infrequently the castings lie in clusters, but show few traces of coiling.

"The fine cleaved slates have yielded few castings, but faint shallow tracks are not rare. They are usually very long, and average two lines in diameter.

"*Neretites monensis* of Binney was a worm-track found in a blue slate. The dimensions are not given, but the worm-track was described as meandering and consisting of about one hundred segments with traces of feet and cirri, and terminating in an oval-shaped head.

"An examination of Binney's figure shows that the segments cross the worm-casting obliquely, and that they are in line with a shear structure developed in the slate. Indeed, the shearing is shown by the artist to join with the segments, so that the latter appear as slight dislocations of the casting. The segments are clearly no part of the worm-track, but have been induced by shearing, a fact still further brought out in the figure by the dragging out of one side of the casting along its upper loop.

"The 'oval-shaped head' is figured as a depression against which the cast abruptly stops. It looks like, and probably is, a worm-burrow.

"*Chondrites informis*, McCoy.

"Among the worm-casts collected by Mr. Lamplugh in the course of his examination of the slates there is a series differing from any hitherto described, and of larger size.

"The castings vary in size from a diameter of three to seven lines. They are composed of rather coarse grains of sand, which are partially compacted together. The matrix upon which they lie, often in high relief, is a slaty grit. A few of the castings are solitary, and when well preserved show a gradual reduction in diameter towards one extremity. More often they occur in clusters, lying parallel to or overlapping one another. Where they overlap, subsequent crushing has obliterated, to some extent, the lines of apposition between contiguous castings, so that they appear at first sight as branching or forked structures.

"Their resemblance to *Chondrites informis*, McCoy, is so very close that we include them in this species.

"Brachiopods are not known with certainty, for though the oval depressions described as footprints by Grindley and Taylor were afterwards doubtfully referred to as the casts and trails of bivalves and the impressions of *Lingula*, neither figures, specimens, nor facts which can be verified, are available to justify their retention.

"The figures and descriptions of the supposed *Lingulella davisii* published by Binney might serve equally well as figures and descriptions of nodule masses still *in situ* in the slates, and wholly inorganic in origin.

"The casts and trails of Grindley and Taylor can be similarly duplicated by hollows left by the weathering out of nodules, and by worm-tracks."

The writer of the present memoir fully agrees with Mr. Bolton that the supposed foot-prints, fucoids, *Lingulae*, and *Orthoceras* previously described were probably all nothing more than the impressions of nodules or worm-casts, and the fauna of the slates is therefore reduced to the three species of the latter: — *Palæochorda minor*, McCoy, *Pal. major*, McCoy, and *Chondrites informis*, McCoy. To these Mr. Bolton adds *Æglinæ* or *Asaphus*; *Dictyonema* (*Dictyograptus*) *sociale*, Salter; and *Dendrograptus flexuosus*, Hall; which he describes as follows¹:—

"In 1892 the intaglio cast of a trilobite was found by the writer²

¹ While the following descriptions are quoted verbatim from Mr. Bolton's paper, the order of the sentences has been slightly changed, and a few passages of which the sense has been previously given are omitted.

² "On the Occurrence of a Trilobite in the Skiddaw Slate of the Isle of Man." *Geol. Mag.*, dec. 3, vol. x., 1893, p. 29.

in a crush-conglomerate at Ballastowell, near Ramsey, and in 1893¹ a few other fossils (*Dictyonema* and *Dendrograptus*) were added from the slates of Cronk Sumark, near Sulby Glen station. . . . A diagnosis, already published in the *Geological Magazine* [of the first-mentioned is as follows :—]

"*Eglina* or *Asaphus*.

IMPRESSION OF BODY AND PYGIDIUM.

"Thorax of six rings; axis convex and of uniform width; body rings narrow and well marked off from one another. Pleuræ very broad, twice the width of the axis; grooves deep, broadening towards the extremities, and disappearing a short distance from the axis; extremities directed backwards. Pygidium a little more than half the length of the thorax; width double the length; axis flattened, convex, and ending bluntly in the middle of the pygidium.

"*Observations*.—From the presence of six thoracic rings, grooved pleuræ, and semi-circular smooth pygidium with feeble axis; the writer was inclined to class the specimen as an *Eglina*, but Dr. Henry Woodward has kindly pointed out that it differs from *Eglina* in the sides of the axis being parallel along their whole length, and in being convex whereas in the former the axis diminishes in breadth from before backwards, and is flattened.

"From a careful comparison of the specimen with others from the Cambrian of North Wales, Dr. Woodward is of opinion that it might with equal propriety be placed in the genus *Asaphus* as *Eglina*. Unfortunately the specimen is too distorted and fragmentary to settle the point."

[With regard to the other fossils], "prolonged search resulted in the discovery of two small splintery masses of slate, each bearing *Dictyonema* and *Dendrograptus* in association. The former genus was most numerous, fragments of nearly a dozen individuals being present; of the latter genus only two specimens were clearly distinguishable.

"In the north quarry [at Cronk Sumark], from which the specimens were obtained, the slates are strongly cleaved and break up readily into irregular shuttle-like masses. The cleavage planes form an acute angle with the bedding, which is frequently indicated by bands of colour. The slates are much iron-stained, and in close association with grits and the remarkable 'crush-conglomerate' described by Mr. Lamplugh.

"*Dictyonema* (*Dictyograptus*) *sociale*, Salter.

"Remains of not less than eight individuals were found lying in close apposition upon the surfaces of two narrow splintery slabs of slate.

"Two individuals are fairly well defined, and show clearly the bifurcation of the branches. Each consists of about six main branches which bifurcate twice, and are arranged parallel to one another in the close radiate order so characteristic of the species.

"Transverse filaments, or dissepiments, are not well defined, except in the case of the tertiary branchings where they are very oblique.

"On one slab, the individuals lie without any order as if drifted there; on the other, three individuals lie at equal distances apart and pointing in the same direction, and are at right angles to a specimen of *Dendrograptus flexuosus*.

"A direct comparison of the Isle of Man specimens with well-defined forms of *D. sociale* obtained from Borth, Tremadoc, Wales, shows a close similarity, extending even to the character of the rock, and the abundant presence of iron-staining in both.

Dendrograptus flexuosus, Hall.

"Fragments of three individuals of this species are associated with those of *Dictyonema sociale* already described. The frond expands rapidly and

¹ "Observations on the Skiddaw Slates of the Isle of Man." *Brit. Assoc. Rep., Notts*, 1893.

noted that this genus has not been recorded from the Skiddaw Slates of the Lake District, the lower part of which offer a probable correlation with the Manx Slates (see seq., p. 114-6). On the whole, therefore, it has been thought preferable to await further evidence before including either *Trilobites* or *Graptolites* in the fauna of the Manx Slates.

Petrography of the Manx Slates and of the Crush-Conglomerate.

The following account of the petrographical characters of the Manx Slates, and the corresponding account of the igneous rocks given in Chapter VIII., p. 296, are mainly based upon the work of Professor W. W. Watts. Before relinquishing his post on the Geological Survey to undertake his present duties at Birmingham, Professor Watts had made considerable progress in the petrographical examination of the Manx rocks collected during the course of the survey, and had also visited the Island to study their mode of occurrence in the field, with the intention of contributing a full account of the subject to the present memoir. Unfortunately, owing to the pressure of other work, Professor Watts has found himself unable to complete his labours, but has handed over to me his notes and descriptions of a large number of slides, which have enabled me to prepare the following general account of the petrology of the rocks. Unless otherwise stated, the descriptions of slides given in the following pages are taken nearly verbatim from Professor Watts's notes.

General Petrographical characters of the Slate series.

As their field-structures would lead us to expect, the chief petrographical characteristic of the Manx Slates when microscopically examined is the extreme and intimate deformation which they have generally undergone, giving rise to structures on a minute scale in the 'grain' of the rock that are visible to the unaided eye in mass. Among these are the *flaser* or drag-structure, and the strain-slip or *ausweichungs* cleavage, which are often beautifully exhibited in slides prepared from the slate-rocks. In intimate association with these structures and apparently due to the same cause, there is usually some mineral alteration of the constituents of the rock, this being most marked in the finer sediments and least marked in the coarser. The predominant feature of this alteration is the more or less abundant production of sericite along the planes of movement, and the development of 'strain-shadows' in the quartz, or sometimes its complete granulitization.

Besides these general effects, there is in certain districts a much greater degree of mineral alteration by which other new minerals make their appearance in the slates, sometimes in such abundance as completely to alter the original character of the rock, transforming it into a true mica-schist, occasionally garnetiferous.

This more severe metamorphism is of the type which petrologists usually regard as denoting thermal alteration by igneous rocks; but the field-evidence points to a very close relationship between the dynamic movements and the alteration of the rock; and, moreover, where local metamorphic effects of igneous intrusions are exposed to examination they appear to be independent of and separable from the wider regional effects.

This question as to the relative values of contact-alteration and of dynamo-metamorphism in the Manx Slates was one to which much attention was devoted during our survey, and a large quantity of material was collected for petrographical investigation, so that we hope eventually to be able further to elucidate the matter. Meanwhile a general outline of the problem with a few illustrative descriptions will be given in subsequent pages.

The usual petrographical character of the sedimentary rocks of the series may be gathered from the following descriptions of slides at the Geological Survey Office. The prefixed numerals are in all cases the reference-numbers attached to the slide in this collection.

Flags and Banded Slates.

The first slide is from a fresh unweathered specimen of the *Lonan Flags* obtained in the *Laxey Mine*.

[E. 2521.] *Lonan Flags*: From the 255 fathoms level of *Dumbells Shaft*, *Laxey Mine*.

Macro. Gritty phyllite, contorted and with strain-slip.

Micro. A finely-banded, slightly gritty slate, the clastic structure almost solely visible in the coarser bands, the finer being concealed in calc-mica-schist, or a phyllite almost solely made up of contorted sericite with little lenticles of quartz (original grains) and calcite. In these layers strain-slip occurs and is beautifully brought out by polarized light, when the sheeny structure is visible. The coarser rock consists of granules of quartz amongst mica flakes and small granules of calcite.

A few slides were cut from specimens of the slightly calcareous nodules of the *Lonan Flags*, in the hope that they might reveal traces of organisms, but none were found. The two following slides represent the average character of the nodules.

[E. 2811 and E. 2810.] Nodules in *Lonan Flags*, *Douglas Head*.

[E. 2811.] *Micro*. A very fine angular quartz-grit with a calcareous cement; a little detrital mica is present and a good deal of fine secondary sericite; decomposed felspar grains seem about as abundant as those of quartz.

[E. 2810.] *Micro*. Decidedly coarser than above, with a larger proportion of calcite matrix; tourmaline, epidote, felspar in abundance, chlorite, slate fragments and quartz-granulite fragments.

An interesting point in connection with these nodules is that they sometimes appear to show 'selective' metamorphism, being altered to a greater extent than their gritty matrix, probably on account of the original difference of composition. This was especially noticed in a nodule from the flags at *Gob ny Ow*,¹ *Port Cornah*, the slide [E. 2510] showing a develop-

¹ Place names in italics are those not given on the one-inch map.

ment of garnet with epidote, sphene and zoisite. The matter will, however, require further investigation.

The next slide is from a hard band in the crushed slate bordering the crush-conglomerate of Sulby Glen. It is a good example of modification by movement, with comparatively unimportant mineral alteration.

[E. 2422.] Hard slate : *Tholt-e-Will* glen, 200 to 300 yards above hotel.

Micro. Very much crushed phyllite ; all the particles of lenticular shape, with good strain-slip and shearing-structure and free development of satiny sericite. The coarser portion is not traceable as a band, but is a good example of phacoidal structure. The twisting of the lenticles is along the foliation, the contortion of which produces the strain-slip, so that except the discontinuity of the coarse portion there is no other evidence of more than one movement, which must have been an intense one.

Fine and Coarse Grits.

Of the four following slides, given as examples of the finer grits, the first [1812] is from an unweathered thin sandy band in the slates of Langness (probably Lonan Flags, see p. 178), obtained from a mining shaft ; the second [2514] is from a much thicker band at the margin of the Agneash Grits, obtained from a deep mine in the Cornah valley ; the third [2814] is from an isolated gritty band in the slates of the middle of the Island ; and the fourth [2387] from the thick band of Magher-e-breck, in the N.E. of the Island, described at p. 140, which is included with the Agneash Grits.

[E. 1812.] Grit from mining shaft at Langness Point.

Micro. A medium quartz-felspar grit with some slate fragments ; somewhat crushed, but without much new mineral development ; grains fitting together and not much ground-mass except calcite.

[E. 2514.] Grit, 3 ft. band ; from bottom of shaft, 174 fathoms, North Laxey Mine.

Micro. A fine, even, angular, quartzose grit with a cement of carbonate of lime (ophitic).

[E. 2814.] Slaty grit : Greeba Mtn., 100 yards S.E. of slate-trail.

Micro. A very interesting slide of a much crushed quartz-grit, in which the fragments have a marked linear arrangement ; at right angles to this is a slightly irregular strain-slip which, crossing the other structure, makes the fragments phacoidal, and they tail off into fibrous white or pale brown mica ; there is a good deal of sericite and some chlorite between the grains which are very close-packed, giving a sort of quincuncial pattern to the slide ; very few rock-fragments.

[E. 2387.] Pale grit ; quarry 250 yards N. of Magher-e-breck, Maughold.

Micro. An ordinary quartzose grit with angular grains very close-packed and little matrix in which chlorite and sericite are developed. There is no visible evidence of secondary quartz-growth as in the quartzites. It has been somewhat crushed. Quartz when smaller than .03 inch, not rounded ; many grains very "dirty" ; one grain of zircon ; sometimes several adjacent grains behave as an optical unit.

The following is the description of the curious boss or lenticle of quartz-rock in the west of the Island, south of Kirkmichael, described on p. 137.

- [E. 2102.] Quartzite ; crag, west side of road 120 yards N.N.E. of branch to *Skeristel Beg*, Michael.

Micro. Almost the whole of the fragments of this are quartz, but there are a very few of felspar ; not much alteration of the ground-mass : some of the grains well rounded, and ground-mass not in great plenty ; a little detrital mica, both brown and white.

The next two slides, one from the southern coast and the other from the western interior, afford good examples of the effects of shearing upon grit-bands associated with slaty rocks.

- [E. 1984.] Sheared quartzo-felspathic grit ; outer *Cronnag Rock*, Bay ny Carricky.

Micro. Quartzose grit with some felspar, but no rock-fragments ; crushed ground-mass crypto-crystalline with sericite.

- [E. 1969.] Sheared bluish-grey grit ; *Glen Dhoo* in Glen Rushen.

Micro. A quartzose grit with angular fragments, much crushed, and with micro-flaser structure ; the grains all "tailing" off into the matrix, with sheaves of mica ; the ground-mass intensely crushed, with banded structure in which layers rich in granulitic quartz, sometimes becoming fairly coarse, alternate with layers rich in sericite, which is very freely developed.

We have next to deal with the group of coarse-grained or pebbly grits. These besides exhibiting many instructive crush-phenomena, are especially interesting in sometimes containing small fragments of andesite, referred to on p. 49, along with other rock-detritus derived from land which was undergoing erosion during the deposition of the grits, thereby furnishing our only information respecting that land. The first three are from the south-eastern coast ; the fourth [1967] from the west coast ; the fifth [2131] from the western slope north of Kirkmichael ; and the sixth [2425] from the northern part of the massif.

- [E. 2812.] Pebbly grit : St. Ann's (Santon) Head.

Micro. A coarse grit, mainly quartzose, but with fragments of fine grit and slate in it. The quartz is very much shattered, having undulose extinction, brecciated, with the unseparated portions divided by very fine quartz completely granulitized, and sometimes with a structure resembling a rude microcline twinning developed in it.

- [E. 2813.] Sheared grit : west side of *Keristal* near Port Soderick.

Micro. A finer quartz-grit, not so much crushed as usual ; several rock-fragments occur, and, amongst them, several slivers of slate and one or two large angular fragments of it which are squeezed out at their ends into fine shreds. They appear strangers to the rest of the rock and may have been in folds, though there is nothing visible to prove this. I think it rather more likely they may have been clay-galls, torn up by subsequent rock-movement.

- [E. 1959] Coarse dark bluish-grey grit : north side of Cass-ny-Hawin Head.

Micro. A coarse grit in which quartz is predominant, all the grains being markedly angular ; some of them having certainly been derived from the porphyritic quartz of a quartz-porphry. They have suffered much from movement since they were embedded in the grit, and they show first undulose extinction, then partial, and finally complete granulitization. Detrital grains of felspar mainly converted into a micro-aggregate, iron-ores and muscovite are common ; besides these, there are large and small grains of slate, granulite, and at least

one fragment, and probably more, of a fine-grained (non-porphyrific) felspathic *andesite*. The ground-mass is fine-grained and detrital, and has sericite abundantly developed in it.

- [E. 1967.] Dark bluish-grey grit showing linear stretching: beach under *Glion ny Goayr*; s. of Niarbyl Bay.

Micro. This grit contains a much larger proportion of rock-fragments and a smaller one of quartz than the others examined. The latter are in most cases strained, crushed, granulitized, and broken, and the whole rock has evidently suffered much from crushing. Slivers of very fine dark slate are conspicuous. They are intensely contorted and dragged into the finest interspaces in the grit. The rock appears to be a variation of the crush-conglomerate in which there was not enough shaly matter to form a flowing matrix, but a preponderance of hard material to make a *crush-grit*.

- [E. 2131.] Crushed coarse ashy-looking grit: small quarry 200 yards E.N.E. of Creggan Mooar, Knocksharry.

Micro. A *much-crushed* quartzose grit, a few of the grains being rounded; rock-fragments not so common as in [E. 1967]. Slivers of slate, contorted, and at least two undoubted fragments of *andesite*. Sericite is the most abundant matrix-mineral. Apparently originally a grit, which is approaching the crush-conglomerate condition.

- [E. 2425.] Coarse quartzose grit: Braid Foss, Glen Auldyn, E. of B.M. 5409.

Micro. This appears to be an advanced condition of the state of things existing in [1967.] The crushing has been carried so far that the boundary between grains and groundmass is not a very definite line when seen under non-polarized light, while with polarized light the edges of the grains are seen to become highly granulitized and to shade off into the 'matrix'. Simple quartz grains, not more than .05 inch in diameter; larger grains are granulitic aggregates up to 0.1 inch diameter.

Slates.

The two following slides were cut to investigate the supposed organic (graptolite) structures referred to on p. 94; besides showing the inorganic character of the structure in both cases, they will serve to illustrate the general characters of the less altered slate-rocks of the series. The localities are on the northern margin of the massif, respectively west and east of the mouth of Sulby Glen.

- [E. 2846.] Slate, with supposed Graptolite (see p. 94). Crag on summit of Gob y Volley.

Micro. This is a cleaved rock with perfect lineated structure, every fragment being elongated with the cleavage and somewhat phacoidal in shape, while it is sheeny throughout with a mat of sericite. Thin contorted layers with rather larger micas wander across the slide, pinched off in places and making a low oblique angle with the cleavage. The supposed fossil is a quartz-vein, on one side of which the cleavage is beautifully frilled and traversed by a strain-slip. The "*Dictyonema*" is undoubtedly the outcrop of this structure.

- [E. 2847.] Slate with supposed Graptolite (see p. 94): west quarry, Cronk Sumark, Sulby.

Micro. The rock is a slightly gritty phyllite with all the minute particles of quartz, etc., phacoidal and with fair strain-slip running about at right angles to the general lineation as

organic remains of the same kind, have proved under microscopic examination to be of inorganic origin. This subject will be further referred to after the descriptions of the specimens have been quoted.

In his recent paper¹ Mr. Bolton has critically discussed the previous palæontological literature, and in the following passages he sums up the work of his predecessors and the result of his own researches.

"In 1862 Mr. J. [E.] Taylor² described certain supposed imprints in the slates of Dalby. These imprints were said to resemble the dotted outline of the *Protichnites* figured in Owen's *Palæontology*.

"Mr. Mackie, Editor of the *Geologist*, thought that the impressions looked more like portions of gigantic *Lingulæ* or some fibrous shell. Mr. Salter denied their organic origin altogether, and Mr. Lamplugh informs me that the impressions were probably the hollows left by the decay of the slightly calcareous nodules, which occur rather abundantly in some localities.

"In 1863, a paper was read by Mr. Taylor³ before the Manchester Geological Society, in which he mentioned the discovery by Mr. Thos. Grindley of a fucoid, and also avers that behind the Castle Mona Hotel he himself discovered both fucoids and the tracks and castings of worms.

"At Mount Craig he found the remnant of an *Orthoceras*, the specimen showing the chambers and also the gradual tapering of the body of the shell.

"In the absence of either the specimen or of any figure, neither of which seem to have been exhibited, very little reliance can be placed upon the description.

"It is not unlikely that it refers to some partially weathered-out worm-casting, or to thin intersecting mineral veins, which in these rocks often simulate chambered organisms.

"Profs. Harkness and Nicholson⁴ in 1866 recorded the finding of *Palæochorda major*. Mr. E. W. Binney⁵ next took up the work in 1877, and published figures and descriptions of worm-tracks which he named *Nemerites monensis* and *Neretites monensis* respectively. Worm-burrows (*Scolites*) were also mentioned, and certain oval structures which he supposed had some faint resemblance to *Lingula*, but which Mr. Lamplugh thinks may have been the cross-sections of worm-casts.

"Whatever these latter may have been, one was somewhat doubtfully referred by Binney to *Lingulella davisii*.

"In the succeeding year Binney⁶ figured and described the supposed fucoid found in the glacial drift at Laxey, and from a superficial resemblance of the specimen to *Psilophyton cornutum* of Lesquereux, he was led to name it *Psilophyton monense*. In a later communication, Binney⁷ states that Dr. Dawson was of opinion that the supposed plant more

¹ "Palæontology of the Manx Slates," Manchester Memoirs, vol. xliii. (1899), no. 1., pp. 1-15, with a plate.

² "Supposed Imprints in the Lower Cambrian Beds of the Isle of Man." *Geologist*, vol. v., 1862, p. 321.

³ "Cambrian Strata of the Isle of Man." *Trans. Manch. Geol. Soc.*, vol. iv., 1863, p. 285.

⁴ "The Lower Silurian Rocks of the Isle of Man." *Quart. Journ. Geol. Soc.*, vol. xxii., 1866.

⁵ "A Notice of some Organic Remains from the Schists of the Isle of Man." *Proc. Manch. Lit. and Phil. Soc.*, vol. xvi., 1878, p. 102.

⁶ "Notice of a Fossil Plant found at Laxey, in the Isle of Man." *Proc. Manch. Lit. and Phil. Soc.*, vol. xvii., 1878, p. 85, and *Manch. Memoirs*, 3rd Series, vol. vi., 1879, p. 214.

⁷ "Remarks on a Fossil Plant found at Laxey, in the Isle of Man." *Proc. Manch. Lit. and Phil. Soc.*, vol. xviii., 1879, p. 19.

nearly resembled *Buthotrephis harknessi* of Nicholson; it is well to bear in mind, however, that Dr. Dawson was guided in his determination by the description and figure, and not by an examination of the specimen.

"Prolonged research amongst the slates by many recent workers has revealed no trace of true fucoids, and, as we shall see later, the supposed fucoids were, in all probability, the casts and tracks of *Palæochorda*. In the absence of descriptions, figures or specimens, we are forced to reject the supposed fucoidal structures of Taylor, Grindley and others.

"*Psilophyton monense* of Binney calls for more attention. It was described as follows: 'The stem is thick, dichotomous, divisions variable in distance, the terminal ones short, pointed, nearly equal in size and length, surface nearly smooth. The branches in the lower part are thick comparatively to their length. The surface of the stem appears to be smooth, and affords no evidence of striæ or scales.' A woodcut accompanies the description, but is too coarsely drawn to illustrate anything except that there is no dichotomy.

"The specimen was said to run nearly at right angles to the bedding (cleavage), and that it lay upon the surface of a boulder taken from the glacial drift.

"In this case, as with previous writers, there is a lack of positive evidence, but an attempt has at least been made to describe the supposed fucoid intelligently. It is most unfortunate that the woodcut does not increase, but rather nullifies, the value of the description.

"The species cannot be accepted as a good one, nor is there evidence to show that the boulder was derived from the slates of the island. There is no certain knowledge of plant remains.

"Animal remains are of a less uncertain character than the fucoids, but are few in number and species, and far from satisfactory.

"Worm-castings, tracks and burrows.

"Under this head must be placed the *Palæochorda major* and *P. minor*, McCoy, once regarded as fucoids.

"*Palæochorda major* was recognised in the Manx slates by Profs. Harkness and Nicholson, and considered by them of considerable value in correlating the latter with the Skiddaw slates of the Lake district. . . .

"Worm-castings, tracks and burrows are fairly common in many of the Manx slates, and certain grits are almost composed of them. Especially is this the case in the cliffs south of Port[h] Mooar.

"*Palæochorda minor*, McCoy.

"The smallest worm-castings the writer has seen are a series collected by Mr. G. W. Lamplugh. . . .

"The castings are usually in the form of long straight semi-cylindrical rods, rarely occurring in clusters, or showing much trace of coiling. They consist of grains of sand hardened into a fine grit.

"To this species we would also refer Mr. Binney's *Nemerites monensis*. The latter was stated to occur in blue laminated slate at Oakhill, Braddan, and was found during the cutting of the railway from Douglas to Castle-town. It was described as occurring in the form of a simple loop, twelve inches long and one-eighth of an inch in diameter. Mr. Binney's figure agrees very closely with that of *P. minor* figured by McCoy.

"*Palæochorda major*, McCoy.

"Worm-castings, larger than those of *P. minor*, occur abundantly in many of the slaty grits; they vary somewhat in diameter, from three to four lines being a fair average. Not infrequently the castings lie in clusters, but show few traces of coiling.

"The fine cleaved slates have yielded few castings, but faint shallow tracks are not rare. They are usually very long, and average two lines in diameter.

"*Neretites monensis* of Binney was a worm-track found in a blue slate. The dimensions are not given, but the worm-track was described as meandering and consisting of about one hundred segments with traces of feet and cirri, and terminating in an oval-shaped head.

"An examination of Binney's figure shows that the segments cross the worm-casting obliquely, and that they are in line with a shear structure developed in the slate. Indeed, the shearing is shown by the artist to join with the segments, so that the latter appear as slight dislocations of the casting. The segments are clearly no part of the worm-track, but have been induced by shearing, a fact still further brought out in the figure by the dragging out of one side of the casting along its upper loop.

"The 'oval-shaped head' is figured as a depression against which the cast abruptly stops. It looks like, and probably is, a worm-burrow.

"*Chondrites informis*, McCoy.

"Among the worm-casts collected by Mr. Lamplugh in the course of his examination of the slates there is a series differing from any hitherto described, and of larger size. . . .

"The castings vary in size from a diameter of three to seven lines. They are composed of rather coarse grains of sand, which are partially compacted together. The matrix upon which they lie, often in high relief, is a slaty grit. A few of the castings are solitary, and when well preserved show a gradual reduction in diameter towards one extremity. More often they occur in clusters, lying parallel to or overlapping one another. Where they overlap, subsequent crushing has obliterated, to some extent, the lines of apposition between contiguous castings, so that they appear at first sight as branching or forked structures.

"Their resemblance to *Chondrites informis*, McCoy, is so very close that we include them in this species.

"Brachiopods are not known with certainty, for though the oval depressions described as footprints by Grindley and Taylor were afterwards doubtfully referred to as the casts and trails of bivalves and the impressions of *Lingula*, neither figures, specimens, nor facts which can be verified, are available to justify their retention.

"The figures and descriptions of the supposed *Lingulella davisii* published by Binney might serve equally well as figures and descriptions of nodule masses still *in situ* in the slates, and wholly inorganic in origin.

"The casts and trails of Grindley and Taylor can be similarly duplicated by hollows left by the weathering out of nodules, and by worm-tracks."

The writer of the present memoir fully agrees with Mr. Bolton that the supposed foot-prints, fucoids, *Lingulae*, and *Orthoceras* previously described were probably all nothing more than the impressions of nodules or worm-casts, and the fauna of the slates is therefore reduced to the three species of the latter: — *Palæochorda minor*, McCoy, *Pal. major*, McCoy, and *Chondrites informis*, McCoy. To these Mr. Bolton adds *Æglinia* or *Asaphus*; *Dictyonema* (*Dictyograptus*) *sociale*, Salter; and *Dendrograptus flexuosus*, Hall; which he describes as follows¹:—

"In 1892 the intaglio cast of a trilobite was found by the writer²

¹ While the following descriptions are quoted verbatim from Mr. Bolton's paper, the order of the sentences has been slightly changed, and a few passages of which the sense has been previously given are omitted.

² "On the Occurrence of a Trilobite in the Skiddaw Slate of the Isle of Man." *Geol. Mag.*, dec. 3, vol. x., 1893, p. 29.

in a crush-conglomerate at Ballastowell, near Ramsey, and in 1893¹ a few other fossils (*Dictyonema* and *Dendrograptus*) were added from the slates of Cronk Sumark, near Sulby Glen station. . . . A diagnosis, already published in the *Geological Magazine* [of the first-mentioned is as follows :—]

“*Eglina* or *Asaphus*.

IMPRESSION OF BODY AND PYGIDIUM.

“Thorax of six rings; axis convex and of uniform width; body rings narrow and well marked off from one another. Pleuræ very broad, twice the width of the axis; grooves deep, broadening towards the extremities, and disappearing a short distance from the axis; extremities directed backwards. Pygidium a little more than half the length of the thorax; width double the length; axis flattened, convex, and ending bluntly in the middle of the pygidium.

“*Observations*.—From the presence of six thoracic rings, grooved pleuræ, and semi-circular smooth pygidium with feeble axis; the writer was inclined to class the specimen as an *Eglina*, but Dr. Henry Woodward has kindly pointed out that it differs from *Eglina* in the sides of the axis being parallel along their whole length, and in being convex whereas in the former the axis diminishes in breadth from before backwards, and is flattened.

“From a careful comparison of the specimen with others from the Cambrian of North Wales, Dr. Woodward is of opinion that it might with equal propriety be placed in the genus *Asaphus* as *Eglina*. Unfortunately the specimen is too distorted and fragmentary to settle the point.”

[With regard to the other fossils], “prolonged search resulted in the discovery of two small splintery masses of slate, each bearing *Dictyonema* and *Dendrograptus* in association. The former genus was most numerous, fragments of nearly a dozen individuals being present; of the latter genus only two specimens were clearly distinguishable.

“In the north quarry [at Cronk Sumark], from which the specimens were obtained, the slates are strongly cleaved and break up readily into irregular shuttle-like masses. The cleavage planes form an acute angle with the bedding, which is frequently indicated by bands of colour. The slates are much iron-stained, and in close association with grits and the remarkable ‘crush-conglomerate’ described by Mr. Lamplugh.

“*Dictyonema* (*Dictyograptus*) *sociale*, Salter.

“Remains of not less than eight individuals were found lying in close apposition upon the surfaces of two narrow splintery slabs of slate.

“Two individuals are fairly well defined, and show clearly the bifurcation of the branches. Each consists of about six main branches which bifurcate twice, and are arranged parallel to one another in the close radiate order so characteristic of the species.

“Transverse filaments, or dissepiments, are not well defined, except in the case of the tertiary branchings where they are very oblique.

“On one slab, the individuals lie without any order as if drifted there; on the other, three individuals lie at equal distances apart and pointing in the same direction, and are at right angles to a specimen of *Dendrograptus flexuosus*.

“A direct comparison of the Isle of Man specimens with well-defined forms of *D. sociale* obtained from Borth, Tremadoc, Wales, shows a close similarity, extending even to the character of the rock, and the abundant presence of iron-staining in both.

Dendrograptus flexuosus, Hall.

“Fragments of three individuals of this species are associated with those of *Dictyonema sociale* already described. The frond expands rapidly and

¹ “Observations on the Skiddaw Slates of the Isle of Man.” *Brit. Assoc. Rep.*, Notts, 1893.

consists of short flexuous branches which bifurcate regularly and at equal distances. As in the type, the first branchings are placed at an acute angle with each other, the last ones being fairly parallel. The agreement of these specimens with the description given of the species by Hopkinson and Lapworth is very close. They are too badly preserved to show the hydrothecæ, but the regular bifurcation, the flexuous character of the branches, and the close correspondence of size are distinctive."

In spite of Mr. Bolton's confidence in his specimens as expressed in the foregoing descriptions, the writer, after having been permitted, by Mr. Bolton's courtesy, to examine them, still feels much hesitation in accepting the conclusions based upon them, and prefers to await further evidence before using them as stratigraphical guides. The supposed cast of trilobite, of which the somewhat too favourable figure in Mr. Bolton's paper has been taken from an impression in modelling wax enlarged four diameters, appears to have been found in the midst of highly sheared crush-conglomerate (see p. 66). Now, though instances are known, *e.g.*, in the Silurian rocks of Ireland and in the Carboniferous rocks of West Yorkshire, in which fossils have survived the disruption of the strata containing them, such instances have hitherto only been discovered where the parent rock is highly fossiliferous, while in the present case careful search in the unbroken strata which go to make up the 'crush-conglomerate' has failed to reveal any trace of organisms other than 'worm-casts'; and, on the other hand, the surfaces of lenticles of grit in the breccia are often marked and striated by shearing and strain-slip in a manner simulating organic structure. Hence it seems possible that the cast in question may be that of an exceptionally striated grit-fragment in the conglomerate.

The doubt as to the supposed graptolites, though not so strong, has still some weight. Mr. Bolton discovered his two specimens in the scree of a quarry which lies exactly upon the margin of the crush-conglomerate (see p. 59), where the pressures must have been intense, and where, though traces of contorted bedding still persist in the upper part of the quarry, the slate in the lower part of the section has been reconstructed, and mingled with fragments of broken grit-bands. On Mr. Bolton's two small specimens the graptolite-like markings are thickly spread, as if the fossils were abundant; but later searches in the same quarry by Mr. Bolton, as well as by the writer and others, have failed to reveal any further examples; and markings found by the writer on slate-fragments at this locality and at Gob y Volley, a mile to the westward, which were at first thought by Mr. Bolton to be graptolites, have, as already mentioned, proved to be of inorganic origin when sliced and examined under the microscope. Search has also been made in several other localities where black carbonaceous or graphitic slate, such as often forms the matrix for graptolites, was observed—*e.g.*, in the stream east of Slieau Monagh; on the coast at Gob ny Creggan Glassey; on the western slope of Greeba Mountain; on Dalby Mountain, etc.; but up to the present with negative results. With regard to the supposed *Dictyonema*, it may be

noted that this genus has not been recorded from the Skiddaw Slates of the Lake District, the lower part of which offer a probable correlation with the Manx Slates (see seq., p. 114-6). On the whole, therefore, it has been thought preferable to await further evidence before including either *Trilobites* or *Graptolites* in the fauna of the Manx Slates.

Petrography of the Manx Slates and of the Crush-Conglomerate.

The following account of the petrographical characters of the Manx Slates, and the corresponding account of the igneous rocks given in Chapter VIII., p. 296, are mainly based upon the work of Professor W. W. Watts. Before relinquishing his post on the Geological Survey to undertake his present duties at Birmingham, Professor Watts had made considerable progress in the petrographical examination of the Manx rocks collected during the course of the survey, and had also visited the Island to study their mode of occurrence in the field, with the intention of contributing a full account of the subject to the present memoir. Unfortunately, owing to the pressure of other work, Professor Watts has found himself unable to complete his labours, but has handed over to me his notes and descriptions of a large number of slides, which have enabled me to prepare the following general account of the petrology of the rocks. Unless otherwise stated, the descriptions of slides given in the following pages are taken nearly verbatim from Professor Watts's notes.

General Petrographical characters of the Slate series.

As their field-structures would lead us to expect, the chief petrographical characteristic of the Manx Slates when microscopically examined is the extreme and intimate deformation which they have generally undergone, giving rise to structures on a minute scale in the 'grain' of the rock that are visible to the unaided eye in mass. Among these are the *flaser* or drag-structure, and the strain-slip or *ausweichungs* cleavage, which are often beautifully exhibited in slides prepared from the slate-rocks. In intimate association with these structures and apparently due to the same cause, there is usually some mineral alteration of the constituents of the rock, this being most marked in the finer sediments and least marked in the coarser. The predominant feature of this alteration is the more or less abundant production of sericite along the planes of movement, and the development of 'strain-shadows' in the quartz, or sometimes its complete granulitization.

Besides these general effects, there is in certain districts a much greater degree of mineral alteration by which other new minerals make their appearance in the slates, sometimes in such abundance as completely to alter the original character of the rock, transforming it into a true mica-schist, occasionally garnetiferous.

This more severe metamorphism is of the type which petrologists usually regard as denoting thermal alteration by igneous rocks; but the field-evidence points to a very close relationship between the dynamic movements and the alteration of the rock; and, moreover, where local metamorphic effects of igneous intrusions are exposed to examination they appear to be independent of and separable from the wider regional effects.

This question as to the relative values of contact-alteration and of dynamo-metamorphism in the Manx Slates was one to which much attention was devoted during our survey, and a large quantity of material was collected for petrographical investigation, so that we hope eventually to be able further to elucidate the matter. Meanwhile a general outline of the problem with a few illustrative descriptions will be given in subsequent pages.

The usual petrographical character of the sedimentary rocks of the series may be gathered from the following descriptions of slides at the Geological Survey Office. The prefixed numerals are in all cases the reference-numbers attached to the slide in this collection.

Flags and Banded Slates.

The first slide is from a fresh unweathered specimen of the *Lonan Flags* obtained in the Laxey Mine.

[E. 2521.] *Lonan Flags*: From the 255 fathoms level of Dumbells Shaft, Laxey Mine.

Macro. Gritty phyllite, contorted and with strain-slip.

Micro. A finely-banded, slightly gritty slate, the clastic structure almost solely visible in the coarser bands, the finer being concealed in calc-mica-schist, or a phyllite almost solely made up of contorted sericite with little lenticles of quartz (original grains) and calcite. In these layers strain-slip occurs and is beautifully brought out by polarized light, when the sheeny structure is visible. The coarser rock consists of granules of quartz amongst mica flakes and small granules of calcite.

A few slides were cut from specimens of the slightly calcareous nodules of the *Lonan Flags*, in the hope that they might reveal traces of organisms, but none were found. The two following slides represent the average character of the nodules.

[E. 2811 and E. 2810.] Nodules in *Lonan Flags*, Douglas Head.

[E. 2811.] *Micro.* A very fine angular quartz-grit with a calcareous cement; a little detrital mica is present and a good deal of fine secondary sericite; decomposed felspar grains seem about as abundant as those of quartz.

[E. 2810.] *Micro.* Decidedly coarser than above, with a larger proportion of calcite matrix; tourmaline, epidote, felspar in abundance, chlorite, slate fragments and quartz-granulite fragments.

An interesting point in connection with these nodules is that they sometimes appear to show 'selective' metamorphism, being altered to a greater extent than their gritty matrix, probably on account of the original difference of composition. This was especially noticed in a nodule from the flags at *Gob ny Ow*,¹ Port Cornah, the slide [E. 2510] showing a develop-

¹ Place names in italics are those not given on the one-inch map.

ment of garnet with epidote, sphene and zoisite. The matter will, however, require further investigation.

The next slide is from a hard band in the crushed slate bordering the crush-conglomerate of Sulby Glen. It is a good example of modification by movement, with comparatively unimportant mineral alteration.

[E. 2422.] Hard slate : *Tholt-e-Will* glen, 200 to 300 yards above hotel.

Micro. Very much crushed phyllite ; all the particles of lenticular shape, with good strain-slip and shearing-structure and free development of satiny sericite. The coarser portion is not traceable as a band, but is a good example of phacoidal structure. The twisting of the lenticles is along the foliation, the contortion of which produces the strain-slip, so that except the discontinuity of the coarse portion there is no other evidence of more than one movement, which must have been an intense one.

Fine and Coarse Grits.

Of the four following slides, given as examples of the finer grits, the first [1812] is from an unweathered thin sandy band in the slates of Langness (probably Lonan Flags, see p. 178), obtained from a mining shaft ; the second [2514] is from a much thicker band at the margin of the Agneash Grits, obtained from a deep mine in the Cornah valley ; the third [2814] is from an isolated gritty band in the slates of the middle of the Island ; and the fourth [2387] from the thick band of Magher-e-breck, in the N.E. of the Island, described at p. 140, which is included with the Agneash Grits.

[E. 1812.] Grit from mining shaft at Langness Point.

Micro. A medium quartz-felspar grit with some slate fragments ; somewhat crushed, but without much new mineral development ; grains fitting together and not much ground-mass except calcite.

[E. 2514.] Grit, 3 ft. band ; from bottom of shaft, 174 fathoms, North Laxey Mine.

Micro. A fine, even, angular, quartzose grit with a cement of carbonate of lime (ophitic).

[E. 2814.] Slaty grit : Greeba Mtn., 100 yards S.E. of slate-trail.

Micro. A very interesting slide of a much crushed quartz-grit, in which the fragments have a marked linear arrangement ; at right angles to this is a slightly irregular strain-slip which, crossing the other structure, makes the fragments phacoidal, and they tail off into fibrous white or pale brown mica ; there is a good deal of sericite and some chlorite between the grains which are very close-packed, giving a sort of quincuncial pattern to the slide ; very few rock-fragments.

[E. 2387.] Pale grit ; quarry 250 yards N. of Magher-e-breck, Maughold.

Micro. An ordinary quartzose grit with angular grains very close-packed and little matrix in which chlorite and sericite are developed. There is no visible evidence of secondary quartz-growth as in the quartzites. It has been somewhat crushed. Quartz when smaller than .03 inch, not rounded ; many grains very "dirty" ; one grain of zircon ; sometimes several adjacent grains behave as an optical unit.

The following is the description of the curious boss or lenticle of quartz-rock in the west of the Island, south of Kirkmichael, described on p. 137.

- [E. 2102.] Quartzite; crag, west side of road 120 yards N.N.E. of branch to *Skeristel Beg*, Michael.

Micro. Almost the whole of the fragments of this are quartz, but there are a very few of felspar; not much alteration of the ground-mass: some of the grains well rounded, and ground-mass not in great plenty; a little detrital mica, both brown and white.

The next two slides, one from the southern coast and the other from the western interior, afford good examples of the effects of shearing upon grit-bands associated with slaty rocks.

- [E. 1984.] Sheared quartzo-felspathic grit; outer *Cronnag Rock*, Bay ny Carricky.

Micro. Quartzose grit with some felspar, but no rock-fragments; crushed ground-mass crypto-crystalline with sericite.

- [E. 1969.] Sheared bluish-grey grit; *Glen Dhoo* in Glen Rushen.

Micro. A quartzose grit with angular fragments, much crushed, and with micro-flaser structure; the grains all "tailing" off into the matrix, with sheaves of mica; the ground-mass intensely crushed, with banded structure in which layers rich in granitic quartz, sometimes becoming fairly coarse, alternate with layers rich in sericite, which is very freely developed.

We have next to deal with the group of coarse-grained or pebbly grits. These besides exhibiting many instructive crush-phenomena, are especially interesting in sometimes containing small fragments of andesite, referred to on p. 49, along with other rock-detritus derived from land which was undergoing erosion during the deposition of the grits, thereby furnishing our only information respecting that land. The first three are from the south-eastern coast; the fourth [1967] from the west coast; the fifth [2131] from the western slope north of Kirkmichael; and the sixth [2425] from the northern part of the massif.

- [E. 2812.] Pebbly grit: St. Ann's (Santon) Head.

Micro. A coarse grit, mainly quartzose, but with fragments of fine grit and slate in it. The quartz is very much shattered, having undulose extinction, brecciated, with the unseparated portions divided by very fine quartz completely granitized, and sometimes with a structure resembling a rude microcline twinning developed in it.

- [E. 2813.] Sheared grit: west side of *Keristal* near Port Soderick.

Micro. A finer quartz-grit, not so much crushed as usual; several rock-fragments occur, and, amongst them, several slivers of slate and one or two large angular fragments of it which are squeezed out at their ends into fine shreds. They appear strangers to the rest of the rock and may have been infolds, though there is nothing visible to prove this. I think it rather more likely they may have been clay-galls, torn up by subsequent rock-movement.

- [E. 1959] Coarse dark bluish-grey grit: north side of Cass-ny-Hawin Head.

Micro. A coarse grit in which quartz is predominant, all the grains being markedly angular; some of them having certainly been derived from the porphyritic quartz of a quartz-porphry. They have suffered much from movement since they were embedded in the grit, and they show first undulose extinction, then partial, and finally complete granitization. Detrital grains of felspar mainly converted into a micro-aggregate, iron-ores and muscovite are common; besides these, there are large and small grains of slate, granulite, and at least

one fragment, and probably more, of a fine-grained (non-porphyrific) felspathic *andesite*. The ground-mass is fine-grained and detrital, and has sericite abundantly developed in it.

- [E. 1967.] Dark bluish-grey grit showing linear stretching: beach under *Glion ny Goayr*; s. of Niarbyl Bay.

Micro. This grit contains a much larger proportion of rock-fragments and a smaller one of quartz than the others examined. The latter are in most cases strained, crushed, granulitized, and broken, and the whole rock has evidently suffered much from crushing. Slivers of very fine dark slate are conspicuous. They are intensely contorted and dragged into the finest interspaces in the grit. The rock appears to be a variation of the crush-conglomerate in which there was not enough shaly matter to form a flowing matrix, but a preponderance of hard material to make a *crush-grit*.

- [E. 2131.] Crushed coarse ashy-looking grit: small quarry 200 yards E.N.E. of Creggan Mooar, Knocksharry.

Micro. A *much-crushed* quartzose grit, a few of the grains being rounded; rock-fragments not so common as in [E. 1967]. Slivers of slate, contorted, and at least two undoubted fragments of *andesite*. Sericite is the most abundant matrix-mineral. Apparently originally a grit, which is approaching the crush-conglomerate condition.

- [E. 2425.] Coarse quartzose grit: Braid Foss, Glen Auldyn, E. of B.M. 5409.

Micro. This appears to be an advanced condition of the state of things existing in [1967.] The crushing has been carried so far that the boundary between grains and groundmass is not a very definite line when seen under non-polarized light, while with polarized light the edges of the grains are seen to become highly granulitized and to shade off into the 'matrix. Simple quartz grains, not more than '05 inch in diameter; larger grains are granulitic aggregates up to 0'1 inch diameter.

Slates.

The two following slides were cut to investigate the supposed organic (*graptolite*) structures referred to on p. 94; besides showing the inorganic character of the structure in both cases, they will serve to illustrate the general characters of the less altered slate-rocks of the series. The localities are on the northern margin of the massif, respectively west and east of the mouth of Sulby Glen.

- [E. 2846.] Slate, with supposed *Graptolite* (see p. 94). Crag on summit of Gob y Volley.

Micro. This is a cleaved rock with perfect lineated structure, every fragment being elongated with the cleavage and somewhat phacoidal in shape, while it is sheeny throughout with a mat of sericite. Thin contorted layers with rather larger micas wander across the slide, pinched off in places and making a low oblique angle with the cleavage. The supposed fossil is a quartz-vein, on one side of which the cleavage is beautifully frilled and traversed by a strain-slip. The "*Dictyonema*" is undoubtedly the outcrop of this structure.

- [E. 2847.] Slate with supposed *Graptolite* (see p. 94): west quarry, Cronk Sumark, Sulby.

Micro. The rock is a slightly gritty phyllite with all the minute particles of quartz, etc., phacoidal and with fair strain-slip running about at right angles to the general lineation as

indicated by the sheeny development of sericite. The rock has been profoundly affected by movement which has made itself felt pretty well all through the rock about evenly. The rock splits more easily along the lineation than along the strain-slip.

Crush-conglomerate.

The following account of the petrographical character of the crush-conglomerate and its incipient stages is reproduced almost *verbatim*, with some omissions and slight alteration of arrangement, from Prof. Watts' notes on the subject in our joint paper, "The Crush-conglomerates of the Isle of Man," published in Quart. Journ. Geol. Soc., vol. li. (1895), pp. 588-596. In this paper Prof. Watts' descriptions were illustrated by two plates, containing ten figures of the slides, which should be consulted by the reader.

"It is very rare to find in the Manx Slate series any sedimentary rocks, except those of very coarse grain, which have not been crushed and sheared by earth movements. Outside the principal zone of crush and brecciation the rocks still show their original clastic structure, but they begin to show, by much deformation, shearing, and cleavage, the influence of those movements which have produced such grand results in the great crush-zone itself. These rocks may be regarded as the raw material out of which the crush-conglomerates have been manufactured.

"The microscopic observations appear to confirm in all essential points the deductions drawn from the field evidence. They even enable us to go a little further on some points:—To trace the disintegration of the grit bands; to watch the process of 'pebble-making' on a small scale; to see the breaking up of the 'pebbles' themselves into miniature 'crush-conglomerates'; to follow the erosion of the 'pebbles' into single grit-particles involved in slate; and, finally, to state the amount of secondary change which the rocks have undergone.

"It is not proposed to give a full microscopic description of each specimen, only of those which are of prime importance, merely referring to the principal features which are to be observed in the other specimens.

"The original sediments are best illustrated by the following specimens:—

[E. 2403.] Crushed grit: Glen Dhoo Stream, nearly 2 miles west of Sulby Glen.

Micro. A dark-grey, compact grit, with veins running parallel to the shear planes. Microscopically this grit is seen to be made up chiefly of quartz-grains, with a smaller quantity of felspar and a few bits of detrital mica and tourmaline. The largest grains measure '02 inch in length, but the average size varies from '005 to '007 inch in length. In part of the slide the grains show the effects of crushing, and have become phacoidal in shape; the shear planes which curve round them are marked by sericite-flakes. The matrix in which the grains are set is a very fine-grained aggregate of quartz-grains, calcite,

and very minute scales of sericite ; the latter mineral from its relation to the fragments, occasionally encroaching on even the larger grains, must be secondary product.

[E. 2427.] Close-grained grit ; same locality as last.

Micro. This is a still finer grit, which is more crushed than that last described, so that all the grains are phacoidal in shape and are set in a plexus of minute flakes of sericite and pale-brown mica. It has evidently undergone some chemical change.

[E. 2414.] Grit cut into 'pebbles,' which are only just being disconnected (see p. 132) : eastern side of Glen Dhoo stream, opposite farmstead.

Micro. The two slides cut from this specimen are extremely instructive, as they show fine puckered slate in contact with fine-grained grit, just the kind of junction which one would expect to throw light on the progress of the crushing. The junction is irregular, rounded promontories of the grit projecting into the slate, and fine crushed shreds of slate running into the gulfs and bays between. Occasionally bits of grit are quite isolated from the main mass, and form as it were islands in the slate. Where this occurs the straits of slate are highly puckered, and often have a fine strain-slip cleavage developed in them, which does not, however, penetrate into the grit. These divisional planes vary in direction in different parts of the slide and appear to be here merely a local phenomenon, due to the pinching of the slate in the jaws of the grit. It bears no relation to the incipient separation of the grit promontories into islands, which must be attributed to another and earlier movement.

The dividing of the grit band into fragments can almost be watched in the two slides cut from this specimen. The *dissecta membra* vary in size, from fairly large patches to those which contain only a few grit-particles, and even these are beginning to go to pieces, so that one is compelled to believe that many of the separate grit-particles in the slate, which are evident strangers there, have been floated off from the grit-band, and are the ultimate term of the disintegration.

"*The Crush-Conglomerate.* The slides from the crush-conglomerate belong to two groups: (a) those which are taken from individual fragments or 'pebbles,' generally the larger ones, and (b) those which show the microscopic aspect of the conglomerate itself and its smaller 'pebbles.'

"A remarkable feature about the crush-rocks is, that in spite of the immense amount of mechanical disturbance which they have undoubtedly undergone, they have suffered comparatively little mineralogical change. The slate of other areas presently to be described exhibit locally much more mineral change than has been detected in the zone of crush, so that the amount of change found in particular specimens of the conglomerate, such as [E. 2412], need not necessarily be connected with the actual brecciation. A specimen to be subsequently described will show that the conglomerate itself has sometimes suffered from a later thermal metamorphism.

"Two specimens and four slides of the 'crush conglomerates' have been chosen for description:—

[E. 2413.] Band of pale breccia in darker breccia. Lowest crags on eastern side of the Sulby river, at *Cluggid* junction.

Macro. This specimen breaks with a slabby fracture, which is seen on the cut surface to correspond to a banding of the specimen, at first resembling bedding. This direction corresponds with a grit-band traversing the fine slaty material in the middle of the specimen. Parallel with this, on each side run one or more bands of conglomerate, generally consisting of light-coloured fragments in a darker matrix; some of the fragments are, however, darker than the matrix. Traversing all these bands at an angle of about 30° or 35° runs a close cleavage, the planes being lead-coloured and marked by a deposit of exceedingly fine chloritic matter. This is the "shear-cleavage" previously described (p.78), and its intersection with the slabby structure produces a streaking on the surface of the latter. The slide described is cut at right angles to all three structures.

Micro. In the slide, the fine band is seen to be a grit made up of angular quartz-grains varying from .002 to .001 inch in length. The coarse bands are conglomeratic, and consist of fragments from .100 to .125 inch long, set in a slaty matrix; this frequently contains grit-particles set in a fine-grained fibrous material, which appears to be chiefly chlorite. A fine slaty substance of this description makes up the fine dark laminae which separate the conglomerate-bands from the grit and from each other.

The fragments in the conglomerate-bands are made up chiefly of grit similar to that just described; of still finer grit; and of slaty rock in which mica is rather freely developed. No fragments of igneous rocks, or indeed of any other rock than those just mentioned, have yet been discovered in the crush-conglomerate.

Signs of great crushing are at once observable throughout the slide; faulting, contortion, and cleavage are all present, and the quartz-particles in the grit, and especially in the slate, are nearly all phacoidal in outline.

Turning next to the divisional planes to be seen in the slide the following phenomena are important. Taking the main grit-band as a direction of some significance, and without stopping to inquire exactly whether it represents bedding or what not, we find that it bears no relation to other very important structures of the rock. The "shear cleavage" is well developed throughout the rock, and especially in the finer-grained portion. It is a true contortion-cleavage, and it appears to be the same as "*ausweichungscleavage*" and the "*strain-slip*" cleavage of Bonney. This structure, when best developed in the slaty matrix, is at an angle of 30° to the general direction of the grit-band; it runs in the same direction in the slate-fragments. It is noteworthy that it is only in such fragments as have their laminae at right angles to the strain-slip direction that the structure is at all characteristically shown; these alone show contortion clearly. Those otherwise orientated are merely crushed, and do not display so clearly the reason for the cleavage-planes which traverse them. The difference of 30° in the directions of the lineation of the rock and of its cleavage shows that the latter structure is to some extent independent of the former.

That the "shear-cleavage" has acted on the rock when it was a conglomerate is evidenced by two facts. When an edge of a fragment is at right angles to the shear-cleavage the fragment and the matrix are seen to have been contorted together and

even faulted. The shear-cleavage is perfectly developed only in the slaty matrix and slate-fragments, and very imperfectly in the gritty fragments and bands. When, however, there has been exceptional movement and crush, the planes travel from the coarser constituents to the finer.

When, however, an attempt is made to assign each structure in the rock to the earlier or later movements very great difficulties crop up, chiefly owing to the tendency there would be for the shear-cleavage to follow the lines of weakness initiated by the first crushing of the rock.

That the "conglomerate" is cataclastic and not epiclastic might have been, I think, predicted from the examination of the slide and specimen. In the first place, the nature of the conglomerate—slate and grit-particles in a slaty matrix—is, to say the least of it, a very unusual one; it is difficult to see how such a conglomerate could result from a deposit in water. In the next place, the absence of extraneous fragments is most suggestive, all the fragments being such as are found bedded in the Manx Slate series. Further, the examination of the shape of the fragments leads to the same conclusion. Working along the slide from right to left, one seems to be following a bed of grit; first it is slightly bent, next it is more sharply folded and almost faulted, then nearly pinched off by a sharp wrench, and at last it is actually torn off, and one realises that one has been tracing a fragment and not a band; or, rather, that one is watching the actual method of forming a fragment out of a band. This may be seen again and again, and in places smaller bits of such fragments will be seen wrenched off and still standing in close proximity to their parent masses (compare p. 67, Fig. 12).

Few of the fragments in the slides studied are entirely rounded; usually one or two corners are rounded off, while the rest are sharp and angular. A peculiar feature is that some fragments are rounded and 'pebbly' at one end, while at the other they have behaved as matrix and have had other 'pebbles' jammed into them. In one case where this is observable the reason is obvious; the 'pebbly' end is coarse-grained and resisting, the 'matrix' end is made of finer, softer material.

Without going into further minute detail, the appearance of the slide may be thus summed up:—Fragments are bent, twisted, broken, faulted, and floated off from one another; one fragment indents another, or has another bent or broken over it; wisps and shreds of matrix are caught up amongst adjacent fragments, torn, faulted, and teased out, or rounded and made into 'pebbles' where there is more space for them to move; the matrix and fragments are in places so inextricably mixed up that it becomes impossible to discriminate between them.

[E. 2412.] Crush-conglomerate in Druidale stream N. of Close.

Macro. A dark slaty rock or phyllite containing fragments of pale grit. The rock splits into slabs, which are at an angle of about thirty degrees to the minutely puckered foliation; these slabs are defined by the "shear-cleavage." The elongation of the fragments is in the plane of foliation. Owing to the less marked character of the second movement this specimen is very valuable in showing the origin of the conglomeratic structure.

Micro. Three slides have been prepared; two are in the plane of intersection of the slip-strain with the contorted foliation, and almost at right angles to the elongation of the fragments; they consequently show only the strike of the divisional planes,

which appear as cleavage cracks. The slide has a damascened appearance, owing to the direction in which the mica-folia are cut, and the matrix of the rock is rich in sericite, which is clearly a secondary product. The fragments do not show any decisive orientation in this slide nor do they seem to be in any way related to the foliation planes.

The other slide [E. 2412 C.] however, is cut at right angles to the cleavage and foliation, and parallel to the elongation of the fragments, so that it is very instructive. The phyllitic matrix is rich in sericite, and is well foliated. The folia are in wavy bands, with the development here and there of strain-slip cleavage-planes which traverse matrix, or fragments, or both, according to the nature of the material of which they are made; such planes define the slabby surfaces of the hand-specimen. The grit- and slate-fragments are all phacoidal in outline, and are drawn out along the foliation planes, folded, torn, and enwrapped by the folia of the matrix. Fragments are occasionally, but rarely, cut off abruptly, and even when this is the case with one end, the other is frequently drawn out into the matrix. The nature of the fragments and the absence of any extraneous types of rocks must be relied on here to prove that the brecciation has occurred *in situ*.

The whole rock has undergone more mineral change than the specimen [E. 2413] last described.

“Pebbles” in the Conglomerate.—The fragments exhibit a great uniformity, and nothing has hitherto been found in them but the grits and slates. Now, the field evidence has shown that the location of the brecciation has been settled, in the majority of cases, by the existence of thin grit-bands in slate, forming a transition in the series between the main grits below and the slate above. The fragments found in the crush-conglomerates could all be matched either in this transition series or else in the main grits or slates. Although the importance of looking out for the existence of fragments and other strangers was fully recognised and a number of specimens were collected to be tested with this point in view, not a single fragment of any other rock has been up to the present detected. To enforce this point the following four specimens of grit fragments have been selected for description:—

[E. 2409.] From grit-block, 14 feet across, in crush-conglomerate: Narradale stream, W. 5° S. of 838 ft. level on Sulby Road.

This is a fragment from the largest individual block hitherto found in the conglomerate. The block, which was 14 feet in diameter, as described at p. 60, had its outer face smoothed and striated. Within the surface-layer the rock has not been affected by crushing, as is shown by the character of a slide taken from beneath the crust of the block.

Microscopically this slide is seen to consist chiefly of quartz-grains, the largest of which are a little over .02 inch in diameter. Some of these are rounded and marked off from the matrix by a deposit of dark material. The smaller grains, which are angular, vary from .01 to .005 inch in diameter. One of the grains contains a felsitic inclusion as though the quartz had been derived from a quartz-porphyry, and a few of the grains answer to the matrix of such a rock. Very few grains of feldspar, and one or two of detrital tourmaline, are

present. The matrix is quartzose, with a little sericite and much chlorite. The rock shows no signs of crushing or shearing, and there is practically no new mineral development in it.

- E. 2410.] Grit-inclusion in conglomerate : Sulby Glen under Close.

Micro. The finer grits of this and another similar slide have suffered much more from crushing. The grit contains abundant grains of felspar, as well as of quartz and muscovite, together with particles of iron-ore. Many of the quartz grains are composite, and have been derived from a granitic or gneissose rock. The grains of felspar are frequently dusty with inclusions and decomposition-products interiorly, but are surrounded by a ring of water-clear felspar in optical continuity with the interior.

The grains average .006 inch in longest diameter ; the fine matrix is made up of quartz, twinned felspar, and muscovite. The smaller grains are arranged with their long axes parallel to the plane of movement, and the matrix is chiefly occupied by folia of sericite which wrap round the grains and are evidently a secondary product due to the movement that the rock has undergone. The patches of iron-ores are broken to dust, and spaced out in lines parallel to the movement.

- E. 2411.] Grit-inclusion in crush-conglomerate ; 60 yards N. of Druidale junction of Sulby River.

This specimen is of great interest, because, while collected as a single fragment in the conglomerate, it is quite evident that a little further crushing would have converted it into many fragments with 'matrix' material between them, and would have incorporated them in the body of the conglomerate.

Micro. A coarse, dark, quartzose grit, in which some of the quartz-grains are opalescent. The original sedimentary arrangement of the materials of this rock is entirely lost, and the structures which are left are merely those due to movement. The rock has evidently been a coarse quartz-felspar grit in which quartz predominated, but fragments of slaty and felsitic rocks were also present. The quartz-grains are phacoidal in outline ; they often possess undulose extinction, and they have at times an appearance of twinning. They are often made up of one, two, three, or even more inosculating portions, and they can be seen beginning to divide, the separated portions becoming filled with granular quartz, and every transition down to complete granulation can be followed up step by step.

Even when a grain as a whole has withstood the crushing force, its edges, and especially its ends, pass into a granular quartz with muscovite. Actually inside the grains granulitic patches occur, which were at first mistaken for felsitic matter, but which are now regarded as the products of crushing and granulation. Fragments of striated felspar have been treated in similar fashion, and slaty fragments are flattened and dragged out amongst the more resisting fragments.

Metamorphism of the Crush-Conglomerate.

- [E. 2418.] Baked crush-conglomerate : East side of quarry adjoining dyke, [E. 2390, see p. 305], Kerroo Moor.

Micro. The fragments in this rock are made of quartzose grit rather coarser than the rest of the rock, which consists of very finely granular quartz, with some felspar, and abundant

muscovite flakes not arranged in any definite direction. The fragments have phacoidal outlines and some of them are full of pyrites. The abundance and size of the mica seem to indicate that contact-alteration has taken place, and its irregular arrangement is quite independent of the shearing of the rock. As might have been expected, mica is much more freely developed in the slaty matrix than in the grit-fragments.

The details of the section from which the above specimen was taken are described at p. 59.

Metamorphism of the Slates.

We have next to deal with the mineral structure of the slates in different phases of alteration, but, as previously stated, this branch of the subject will be only tentatively discussed at present.

In the immediate neighbourhood of the granitic masses, the sedimentary rocks are rendered more or less crystalline by the development of new minerals, but the problem which yet remains to be solved is as to the condition of the rock just before the intrusion of the granites. It is clear that the strata had been folded and crushed at some time previous to the intrusion of the principal igneous masses; and if the regional metamorphism referred to on previous pages (pp. 70, 72) be really the result of dynamic movement, as the field-evidence appears to indicate, it is probable that the granites were intruded into rocks which were already much altered. The attempt to disentangle the effects of these two supposed periods of alteration by microscopic examination has not hitherto been altogether satisfactory, though it does not appear to be hopeless. In the field it was thought that an older schistosity could be detected, particularly in the vicinity of the old Cornelly mine (see p. 165), with the newer contact-alteration superimposed upon it, but this point has not yet been made out definitely in the microscope-slides.

Contact-alteration.—Before seeking to discuss the regional alteration, it will be advisable to give a few notes on the mineral condition of the sedimentary rocks in the immediate proximity of the larger igneous intrusions.

The Dhoon Granite, which comes up, apparently with steep walls, through sandy flags not particularly susceptible to mineral change (see Chap. viii., p. 311), causes, so far as we can judge from the exposures (pp. 142-4), very little alteration of the country-rock until we are within a few yards of the actual junction, and even then the alteration is not excessive, as the two following slides will show.

[E. 2489.] Lonan Flags, altered : 3 ft. from junction with granite : quarry at Kionehehin, Dhoon.

Micro. This rock is a fine quartzose grit with an abundant development of pale greenish mica, slightly pleochroic; associated with this is a brown mica, which increases in quantity in one part of the slide; iron-ores, and a little zircon. Beyond the nature of the mica there is not much evidence either of dynamic or contact metamorphism.

[E. 2490.] Lonan Flags, altered : 2 inches from junction with granite ; quarry at Kioneheinin, Dhoon.

Micro. This slide shows a good deal of contortion, which is especially indicated by the presence of a coarsish grit-band now quite granulitic and a good deal sheared. Along its margin a certain amount of brown mica has been formed, which is set amongst somewhat elongated grains of granulitic quartz ; at the corners of the grit-folds, too, there is abundant sericite in the form of 'tails.' The rest of the rock is a very fine grit with abundance of the greenish mica and sericite, muscovite in larger grains, iron-ores, and but little brown mica ; a few bands are much contorted and quite sheeny, and in places tourmaline is well-developed. Judging by the appearance at the edges of the coarser bands, the alteration, with the probable exception of the tourmaline, appears to be as much the result of dynamic action as of thermal action. At one spot a few crystals of triclinic felspar occur.

Conditions similar to the above obtain in regard to the sedimentary rocks surrounding the Oatland Granite, which is intrusive upon Lonan Flags of a somewhat more argillaceous type (p. 185).

[E. 2914.] Baked Flags : N.E. side of Oatland intrusion, near contact.

Micro. This rock is banded, alternately coarser and finer grained ; the coarser bands show clastic grains of quartz set in an aggregate of minute mica-flakes which are probably of secondary origin ; the fine bands are spotted, the clear spots consisting of white mica with an occasional particle of quartz, the darker network in which the spots are set consisting mainly of chlorite. A banded and spotted hornfels.

The Foxdale Granite, however, which is intruded into rocks of a slaty character (p. 165), and, moreover, is known to shelve gradually downward from its outcrop for some distance (p. 506-7), has a wider halo of alteration, though even this is apparently limited to a few hundred feet at the most, and is insignificant both in extent and in the degree of mineral change when compared, for example, with the halo surrounding the Skiddaw Granite of the Lake District. But there is a large tract of highly-altered slate—indeed, a true garnetiferous mica-schist—lying not far to the northward and north-eastward of the granite. This tract has its centre a little over a mile distant from the visible margin of the granite, and the alteration is believed to be of the regional type, in spite of certain facts which might be taken to indicate a direct relationship with the plutonic intrusion (p. 165). Leaving this point for the present, we give the description of two slides cut from specimens of slate close to the granite outcrop.

[E. 2889.] Junction of granite with slate : Renshent, w. of Eairy, near Foxdale.

Micro. This is a granite with altered biotite, in contact with a garnetiferous biotite-schist. The granite bears a little tourmaline and in the slate at the margin there is a mineral like cordierite.

[E. 2803.] Altered slate, in or near lode, in s. cross-cut of 170 fm. level, Potts Shaft, Foxdale Mines.

Micro. A fine-grained white-mica-phyllite without garnets ; there are augen of a mineral with good edges and approximately

hexagonal outline made up of an even and very minute aggregate of highly polarizing fibres; this may be an approach to the formation of cordierite.

The majority of the intrusive dykes which traverse the slates are too narrow to have exerted much metamorphic effect; but the broader examples, whether acid, intermediate, or basic, have had more influence in this direction, and are usually margined by a narrow rim of baked and splintery slate. This kind of alteration may be best studied in cliff-sections where the broader dykes are exposed.

The boss of diabase at Poortown (p. 156) has this baking effect in a marked degree, as is well seen in the small quarry at its eastern edge.

Regional Metamorphism.—The area affected by the regional type of alteration is roughly indicated on the sketch-map, Fig. 29, p. 84. Its limits cannot be sharply defined, as the metamorphism varies considerably in intensity from place to place, and appears to be essentially only a local enhancement of that slight sericitic alteration which affects the whole mass of the slates. This enhancement takes place, however, mainly within a rude belt running parallel to the central stratigraphical axis of the island, and is chiefly prevalent in the banded strata of transitional type which lie between the Barrule Slates and the Grits on the south-eastern side of that axis. Starting at the N.E. corner of the massif, this belt may be traced south-westward, with the strike of the rocks, from the vicinity of the coast near Maughold Head, into the interior along the line of the upper Cornah Valley and the main ridge of Barrule Slates; past Snaefell and Beinn-y-Phott to the central valley near Greeba; across that valley into the broader and more highly altered schistose tract lying north-east of the Foxdale Granite; and thence to the upper reaches of the Silverburn Valley, beyond which its further prolongation is uncertain. It has already been noticed (p. 70) that the position of the belt on the south-eastern side of the structural axis is in many respects analogous to that of the belt of crush-conglomerates on the opposite or N.W. side, and involves the same set of rocks. This correspondence can scarcely be accidental, and it seems conceivable that the differential movements to which these beds were peculiarly exposed (p. 70) led to the production of the crush-conglomerate on the one side, where the superincumbent load was least, and on the other side to a more intimate change of mineral character, where the compressive force was too great to permit of rock-brecciation (p. 76). Whether from this cause or another, the banded slates of the altered zone nearly everywhere show, under the microscope if not to the naked eye, a new development of small mineral crystals, including brown mica, garnet, tourmaline, chloritoid, ilmenite, etc., in addition to the usual sericite; and not only are the slates thus altered, but also the older igneous dykes, especially those of 'greenstone,' traversing the belt (see p. 308). The slate

usually most altered and its new minerals largest and most conspicuous in the immediate vicinity of grit-bands, quartz-veins, other hard bodies; and the appearances suggest that this altered alteration is due to the increased crushing and friction developed along the junction of soft and hard masses.¹

Within the limits of the zone, the alteration is least marked at north-eastern extremity of the island, and increases inland. Following slide will show its character in the cliffs south of Rhod Head.

16.] Striped sandy shale; frilled and sheared. *Traie ny Foillun*, Maughold.

Micro.—The stripe of this specimen is a plane which has been minutely puckered, and in the slide is seen to be crossed, at an angle of about sixty degrees, by a strain-slip cleavage in the slate-bands. In places the grit is torn off, and forms lenticles in the slate. Pale brown mica is developed along the planes of stripe in the slate bands, and it runs into the strain-slip planes in wavy surfaces. The amount of mica present here is very great, but there is much less in the grit-bands. A few colourless needles, which I take to be felspar, occur in the slate, and a few needles of tourmaline are also present. A great quantity of ilmenite in fine needle-like crystals occurs scattered quite irregularly all over the slide. It has no definite orientation. The shredding-out of the coarse beds is observable, but the fragments remain along the line of stripe.

Lenticulars respecting the exposures of similar 'spotted' slates in other parts within the altered belt in this part of the island will be found in the series of topographical details (Chap iv.), wherein also the later discolouring and decomposition of certain portions of the slate in the upper Rhod Valley, possibly by comparatively recent hot-spring action, are also noted.

The next spot within the belt which needs description is in the vicinity of Snaefell, where the alteration has locally reached a more advanced stage. The peculiar interest of this locality lies in the fact that the altered slates occur on the flanks of the mountain at between 1,000 and 1,800 feet above O.D., and that the slates are not only dissected by deep valleys on all sides, but are penetrated by the shaft of a lead mine (p. 526), to a depth of at least 1,000 feet from the bottom of the valley east of the mountain—equivalent to nearly 200 feet below the sea-level, with long tunnels northward under the hill, without discovering any igneous mass adequate to cause the alteration. The most visible intrusive rock, other than the usual small dykes,

¹The alteration seems to be very similar to that recently described by C. A. Raisin in her paper, "On certain altered rocks from near the Ardennes" (Quart. Journ. Geol. Soc. vol. lvii. pp. 55-72), in which it is suggested that the patchy alteration may be ascribed to the action of hot springs. Lenticular grit-bands and quartz-veins would be likely to imprison a small quantity of water, which, when superheated by the movements, might materially facilitate the alteration of the surrounding rock; but in the Isle of Man no evidence was observed that the flow of hot water through the strata near the garnetiferous rocks.

is the Dhoon Granite, the western edge of which lies over two miles distant to the eastward. The two following slides represent the altered slate of Snaefell:—

[E. 2413] Altered Slate: small quarry 150yds. E.S.E. of Snaefell Hotel; about 1,450ft. above O.D.

Micro. A black contorted fine-grained schist with crystals of garnet, with minute needles of a white mineral (? ilmenite); the garnets are perfect rhombic dodecahedra. The rock is a *garnetiferous mica-schist*, with beautiful but irregular strain-slip cleavage; it consists chiefly of the usual pale mica, slightly pleochroic, in wavy folia, separated here and there by lenticles of quartz, varying in size, and generally aggregated. There can, I think, be no doubt that this is secondary and deposited in the opening lenticles. (It is possible some of this may be felspar, but the mineral is much too small for identification; there is, however, a tendency for it to assume oblong and prismatic forms.) The knot-mineral is always garnet, in rhombic dodecahedra giving hexagonal sections, and each garnet is associated with one or more crystals of chlorite. The strain-slip ends up against the garnets. The garnets contain long needles with parallel extinction, the nature of which has not been determined, and the interiors of the crystals are often dusty. The ilmenite needles tend to arrange themselves parallel to the folia as far as possible, but they are longer than the bends and project through them. There is one shredded patch of grit in this specimen.

E. 2415.] Striped and puckered slate: roadside, S.E. side of Snaefell, 1350ft. above O.D.

Micro. This specimen shows alternate bands of grit and slate on its outer surface, and the microscopic slide gives an excellent example of the "cleavage-foliation" of Sorby. The strain-slip cleavage runs at right angles to the stripe, and the cleavage-planes are planes of foliation marked by a deposit of pale brown mica. Where the quartz-grains are large enough to be well seen they have a phacoidal shape, but in the coarser bands the quartz is in complex grains arranged parallel to the foliation. There is a diversion of the cleavage-planes in traversing the grit bands. The rock is a mica-schist.

A good example of the patchy mode of occurrence of garnets in the slate is afforded in a small cutting on the electric-tramline on the south-west shoulder of Snaefell, about 900 yards north-west of the hotel on the high-road. Dark sheared slate, with steeply inclined bedding crossed by a nearly horizontal strain-slip cleavage, includes a band of hard sandy slate an inch in thickness, much spotted and altered, and for an inch on both sides of this band the slate is thickly crowded with clear red garnets, up to $\frac{1}{4}$ inch in diameter. Similar garnets are plentiful for about 6 inches farther, afterwards becoming gradually more thinly scattered, but are still visible on the north-west side, to a distance of 3 feet from the central band, though not so persistent on the opposite side.

[E. 2493.] Garnetiferous Slate: tramline S.W. side of Snaefell, E. of B.M. 1150' O'.

Micro. A phyllite with garnets often of a good shape: a little chlorite often developed in association with the garnets.

In another cutting, where the tram line rounds the northern shoulder of the mountain a short distance below the summit, the highly-sheared slate adjoining a discontinuous quartz-vein contains numerous garnets, up to about $\frac{1}{4}$ inch in diameter; and the same conditions recur around the outcrop of another quartz-stringer in the craggy ground $\frac{1}{4}$ mile to the north-eastward. The garnets sometimes show signs of crushing, though their growth was evidently later than the principal shear-movement.

South-west of Snacfell, on the southern slopes of Beinn-y-Phott and in the upper reaches of the Baldwin River, associated with the altered slates there are a few curiously altered sheared dykes of greenstone, of which some account will be found in Chap. viii., p. 310.

Farther south-westward again, on the eastern side of Greeba Mountain not far below the summit, a remarkable and unusual change is exhibited by a schistose dyke of micro-granite, which shows a new development of garnet and chloritoid, apparently as the result of the regional alteration (p. 318).

Still following the same direction and crossing the central valley at Greeba, we find on its southern slope a pronounced alteration of the slates interstratified with grits, in the lower part of the crags of *Creg y Whualliam* (p. 168). From this point southward the metamorphism becomes rapidly intensified, and expands over a broader area, the change being well displayed in the stream-beds of *Cooillingill* and *Glion Darragh*. Around the heads of these glens, the slate has been metamorphosed into a knotted micaceous schist studded with garnets and other minerals, and the intrusive 'greenstone' dykes are converted into actinolite-schists (p. 164).

This highly altered tract stretches southward for about half a mile, to the crest of the *Archallagan* rise, where it is exposed in two small old quarries; it then appears to fade gradually in this direction, and to merge into the halo of less conspicuously altered slate surrounding the Foxdale Granite; but this portion of the tract is poorly exposed. Westward, the highly-altered phase extends for about a mile, and the slates then revert to their normal condition. In the middle of the tract, at the head of *Glion Darragh*, where the metamorphism is most intense, a shaft of the old Cornelly or Townsend lead mine, previously referred to, has been sunk to the depth of 840 feet. At the depth of between 300 and 400 feet, the shaft passed out of the altered slate into a granitic rock closely resembling the Foxdale granite (p. 315), and the lower workings appear to have continued at the edge of an irregular pipe or boss of the intrusive rock down to the bottom of the mine (see p. 516 for details). This rock is not visible at the surface, and it is only from the accident of the shaft-section that we discover the existence of any massive igneous rock nearer than the Foxdale granite, $1\frac{1}{2}$ miles distant, though the intervening ground is traversed by several small dykes, both acid and

basic (p. 164). The presence of this concealed intrusion and the possibility of its underground extension to Foxdale seem at first sight sufficient to explain the metamorphism of the slates at the surface, but there are several considerations which weigh against this conclusion. In the first place, if the alteration be entirely due to the igneous rock it is curious that the same kind of alteration should not be found in the sedimentary rocks of similar composition which surround the outcrop of the Foxdale Granite; furthermore, the same type of mineral change, somewhat modified, is found in other places in the altered belt, sometimes, as we have seen, under conditions which preclude the possibility of a buried igneous mass within an appreciable depth; and again, there are indications, already alluded to, that the schistose condition was attained prior to the intrusion of the granite. With this statement of the complicated factors, this problem must be reserved for further investigation.

The following slides will show the structure of the altered slates of this area. Some of the altered dyke-rocks are described in Chap. viii., p. 313.

[E. 2668.] Altered slate : *Cooillingill* stream, 100 yds. above B.M. 380' 8".

Micro. Contorted mica-schist chiefly consisting of small flakes of brown and white mica with some larger crystals of brown mica usually set at right angles to the foliation.

[E. 2666.] Altered slate : northernmost old quarry, *Archallagan*.

Micro. Quartz-muscovite schist with augen of garnets in all stages of passage into tangles of chlorite. This specimen proves that the round and hexagonal tangles of chlorite in other slides have been derived from garnets. Also large crystals of chlorite, generally arranged parallel to foliation : a smaller amount of brown mica.

[E. 2669.] Altered slate : w. branch of *Glion Durragh*, N. side of *Archallagan*.

Micro. This is a definite augen-schist, the augen being of garnet, sometimes associated with crystals of brown mica and in other cases of brown mica alone : few large chlorites. There is also another mineral in the augen, which has not been determined.

[E. 2894.] Altered rock : spoil-heap of Cornelly Mine.

Micro. This is a muscovite-schist, well foliated and consisting of quartz, felspar and muscovite. It contains numerous large prismatic crystals of chlorite with straight sides and ragged ends, set sometimes parallel to, and at other times at a high angle, even at a right angle with, the foliation. There are other roundish or hexagonal patches of matted chlorite, round which there are augen of muscovite. All the chlorite contains minute colourless crystals round which there are pleochroic halos.

In another slide [E. 2673] from the same locality as the last, large garnets were still recognisable, though "caten into" by quartz and chlorite.

Continuing the examination of the altered belt south-westward, we find indications in the southern slopes of South Barrole of its persistence at the same stratigraphical horizon; and reach another tract, of very limited extent, in which the

metamorphism is conspicuously intensified, near the head of the Silverburn valley, $2\frac{1}{4}$ miles distant from the nearest outcrop of the Foxdale Granite, and without visible association with any other igneous intrusion. This is best seen in the gullies at *Whallag* and *Reash*, near the Castletown Waterworks Reservoir, under conditions described in the next chapter (p. 169). The highly altered slate is here associated with thick bands of grit and strings of vein-quartz, and the mineral change is most pronounced in the immediate vicinity of these hard masses, where the slate is most crushed. The extent of the change may be judged from the following descriptions of slides:—

[E. 2084.] Altered slate: gully at *Whallag*, adjoining water - works reservoir.

Macro. A crumpled schist with layers of granular quartz separated by folia of white mica on which needles of schorl are recognisable.

Micro. The quartz-mosaic is made of grains with rectilinear edges in contact with one another and without any intervening substance, so that the clastic structure must be secondary. The folia are of tourmaline, bluish brown to pale yellow in tint. The crystals bend round the curves, and at the summit of the latter there is usually a development of coarse quartz-mosaic. Along the planes of much movement the quartz is laden with inclusions. A few small garnets occur.

[E. 2085.] Altered slate: gully at *Whallag*, N.E. side of reservoir.

Macro. Crumpled sericitic quartzose schist, with fewer tourmalines.

Micro. Flattened phacoidal quartz grains set in layers of muscovite with much iron-ore dust; in other layers, a brown fibrous mineral occurs, which is not isotropic but very faintly pleochroic and passes into an opaque brown substance; schorl in isolated needles.

[E. 2086.] Altered slate: gully at *Whallag*, 40 yards above N.W. corner of reservoir.

Macro. A dark phyllite dotted with what look like rotted pyrites and a little very fine schorl.

Micro. Some clear layers of quartz with muscovite, alternating with layers in which the latter mineral is associated with the brown mineral described in [2085]; in these are knots containing quartz (and possibly felspar?); scales of graphite in plenty, imparting a dark colour to the rock; a few tourmalines, but no garnets.

[E. 2087.] Altered slate: bed of Silver Burn 200 yards below top dam, Cringle.

Micro. Dark and light bands fingering into one another, both made of close quartz-mosaic, dirty with inclusions of graphite-dust; the darker layers have rods and plates of graphite in quantity; biotite in crystals, often across the foliation planes.

To the west of the Silverburn Valley, the ground across which the altered belt would pass if prolonged, is much obscured by drift, and yields no further information. If the belt extend to the western coast, it may occupy the great precipices north of Fleshwick, and is inaccessible to observation.

In reviewing the evidence, it is noteworthy that the greatest

degree of alteration is attained where the planes of the dominant "shear-cleavage" are flat or nearly so, which again suggests relationship between the cleavage-producing movements and the metamorphism. It will be observed, also, on examining the transverse sections of the massif given on Plate II. that the altered belt lies near the centre of the synclinal trough, where the rocks are likely to have been buried deepest and where the crumpling and packing of the more plastic beds has been most intense. It is, however, likewise the case that the central zone of the massif embraces the two principal intrusions of granite, and that the dykes connected with these granites, as shown in the sketch-map Fig. 29, p. 84, accompany this zone throughout the island and are not found beyond it. Hence, while the metamorphism cannot be satisfactorily explained by the intrusions alone, these may nevertheless have played their part in raising the temperature of the rock-mass and bringing it nearer to the critical stage. But the actual re-crystallization seems to have been in some way directly dependent upon earth-movement.

Age and Correlation of the Manx Slate Series.

It is natural that an attempt should have been made to correlate the slate-rocks of the Isle of Man with the Skiddaw Slates of the Lake District, their nearest analogues in geographical position and in lithological character; but, as already pointed out, the basis for this correlation is inconclusive, especially since the supposed identification of the Borrowdale Volcanic Series in the Island has proved unfounded (p. 26).

As previously mentioned (p. 27), I have myself made traverses of the Skiddaw Slates in the typical exposures on the mainland, in the hope of more firmly establishing the correlation; but beyond a general resemblance, such as might exist between any two tracts of Older Palæozoic rocks of like composition, I failed to find any definite points of similarity.

Even if we allow the correlation in general terms, the absence, so far as is known, throughout the Island, of the characteristic fauna found in the upper portion of the Skiddaw Slates, seems to limit the possible equivalents of the Manx Series to the lower part of the Skiddaw group. Our knowledge of the Skiddaw Slates themselves, and especially of their lower portion, is still very imperfect; and in fact, as with the Manx Slates, even their order of superposition has not been conclusively established. According to Mr. J. E. Marr, who is our chief authority on the subject, the beds which have yielded most of the fossils appear to constitute only the higher portion of the series, and these "are folded in boat-shaped synclines amongst what is probably a very much greater thickness of older rocks, the palæontology of which is practically unknown."¹ This upper-

¹ J. E. Marr, "Notes on the Skiddaw Slates," *Geol. Mag.*, dec. iv., vol. i. (1894), pp. 122-130.

most "graptolite-bearing portion of the Skiddaw Slates" has been provisionally classified by Mr. Marr as follows:—

2. $\left\{ \begin{array}{l} d. \text{ Milburn Beds} = \text{Uppermost Arenig or Lower Llandeilo.} \\ c. \text{ Ellergill Beds.} \\ b. \text{ Tetragraptus Beds} \left\{ \begin{array}{l} \text{Upper, with } \textit{Didymograptus nanus}. \\ \text{Lower} \end{array} \right. \\ a. \text{ Dichograptus Beds.} \end{array} \right.$
1. *Bryograptus* Beds = Tremadoc Slates.

Hence if we accept the classification which includes the Tremadoc with the Upper Cambrian, even the upper fossiliferous part of the Skiddaw Slates ranges downward through the lowest horizons of the Lower Silurian into the Upper Cambrian, with still a great mass of underlying strata of higher antiquity. Although on the maps of the Geological Survey the tracts of Skiddaw Slates are all coloured as Lower Silurian from lack of any practicable means of differentiation, we find that Clifton Ward, who was mainly responsible for the mapping, fully recognised their downward extension into the Cambrian,¹ and in correlating them with the rocks of North Wales, proposed the following divisions²:—

Arenig Slates	}	Lower Silurian.
Arenig Grit		
Tremadoc Slates	}	Cambrian.
Lingula Flags		

Similarly, Prof. H. A. Nicholson, though at first considering the Skiddaw Slates to be altogether of Lower Llandeilo age,³ afterwards placed them provisionally in the Upper Cambrian.⁴

If, therefore, the Manx Slates were deposited in the same basin of sedimentation as the Skiddaw Slates, but represent, as appears most likely, only the lower portion of the mainland-series, they can scarcely be newer than Upper Cambrian. On these grounds the Cambrian colour and symbol, with a mark of interrogation, have been adopted for them on the published map; and until more satisfactory evidence is forthcoming it is scarcely practicable to attempt a closer definition of their age.

The basis for a comparison of the Manx Slates with the

¹ "The Geology of the Northern Part of the English Lake District," Mem. Geol. Survey, p. 47.

² "On the physical history of the English Lake District," Geol. Mag., dec. ii, vol. vi. (1879), p. 124.

³ "An essay on the Geology of Cumberland and Westmorland." London, 1868.

⁴ "A Manual of Palæontology." 8vo. Blackwood & Sons, 1872, p. 513.
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Cambrian strata of North Wales and of the east of Ireland is even slighter than for the Lake District. In both countries the Cambrian sediments comprise highly disturbed and altered slates, greywackes, grits and quartzites; but during a personal examination of some of the Irish sections I failed to find any salient points of resemblance, and am not aware of any features in the Welsh rocks which, in the absence of fossils, would furnish definite grounds for correlation with the Manx Series.

Estimated thickness of the Manx Slates.

The only method of measuring the thickness of a series so greatly disturbed as the Manx Slates with any approach to accuracy, is to identify the component strata and obtain their thickness separately under favourable conditions—a method which, as we have seen, has unfortunately not been found practicable in this case. All that can be attempted, therefore, is to give some idea of the probable relative thickness of the different divisions, with a vague estimate of the possible value in figures.

Commencing with what we have taken to be the highest member of the series:—the *Barrule Slates*, in spite of their extended outcrop and great depth in the hills of the centre of the Island, may originally have been not more than a few hundred feet in thickness, though now packed to a vertical thickness of not less than 2,000 feet in the vicinity of the Snaefell ridge.

The *Agneash Grits* and corresponding belts of similar quartz-veined grits in the south and west of the Island are known to have a restricted vertical range, even where their outcrops are wide and dips steep. The strata which have been crumpled up to form these belts need not originally have been more than 100 feet or so in thickness.

The *Lonan* and *Niarbyl Flags* and the banded slates of the 'unseparated' tracts must however have been of much greater extent. Their diversity of composition, their downward continuation, without change of type and without any indication of a base, to over 1,500 feet below sea-level in the Great Laxey Mine (see p. 522), and the deep straight-limbed character of the folding which pervades them, seem to necessitate great original thickness; so that even granting the most persistent repetition by folding, we cannot allow less than a thousand feet for the initial thickness of these flags, and shall most likely then be considerably under-estimating them.

By combining these estimates, we obtain for the whole series a possible minimum original thickness of, in round numbers, from 1,500 to 2,000 feet, with the probability that this may be much below the truth.

Conditions of sedimentation.

There are no deposits among the Manx Slates indicative of shore-conditions. Even their sandy portions are comparatively thinly bedded; and in the coarsest grits, viz., those of St. Ann's Head and vicinity, the larger fragments rarely attain a diameter of more than a quarter of an inch. The series appears to have been deposited in a sea of moderate depth, into which a constant but not heavy supply of sediment was swept and widely distributed by currents.

In the absence from these rocks, as from the Skiddaw Slates of the mainland, of any known base, the only evidence of older formations is afforded by the small worn rock-fragments in the grits and flags. These, as stated in the petrographical notes, include abundant grains of vein-quartz, some felspar and mica, and a few relics of older sedimentary rocks, including fine-grained quartzite, greywacke, and perhaps slate, with occasional fragments of andesite. Except in the small obscure outcrop of tuff or brecciated andesite near Dalby, described on p. 163, the Manx Slates appear to include no volcanic material beyond the above-mentioned fragments in the grits.

Tectonic Structure of the Manx Slate Series.

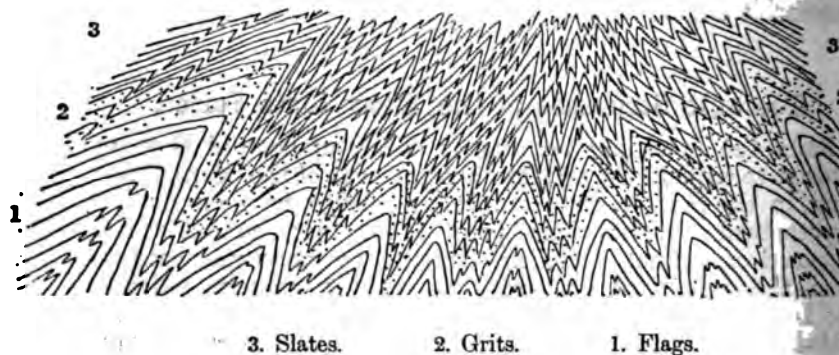
From the preceding account, it will be understood that any attempt to explain the tectonic arrangement of the Manx Slates must, in the present state of our knowledge, be more or less hypothetical. It has been pointed out that, instead of the supposed anticlinal structure, deduced by previous observers from the dominant outward dips on the opposite sides of the Island, the evidence tends as a whole to indicate that the folded belts of strata sink gradually, though irregularly, towards the interior axis, and that the most probable structure is a compound syncline ('synclitorium' of Dana; 'exocline' of Lapworth; 'inverted fan-structure' of Heim).

On a small scale this structure is readily illustrated by laying a few leaves of paper together and crumpling the sheet into a succession of small sharp folds, and then lifting its opposite sides so that the centre forms a trough. The paper in this model gives a diagram of a synclitorium such as might occur if folding took place in beds of slight thickness, which were free to move upwards and downwards. But if, instead of a few leaves, we take a pile of paper several inches in thickness, and seek to make a similar arrangement, we shall find the task of producing a system of isoclinal folds exceedingly difficult; and a corresponding difficulty arises when we attempt to draw a section to represent isoclinal folding in strata of considerable thickness, because of the tendency of the crests and troughs to fill in and become obliterated both upwards and downwards. Hence we often find that in diagrammatic drawings of this kind, sharp folding is represented in only a few thin bands in a section and is more or less

evaded elsewhere. Nevertheless we know that, in nature, folding of this kind prevails throughout great masses of strata, as in the case of the Manx Slates.

It is clear that where thick series of rocks are packed together in closed folds, each individual fold must undergo considerable modification of character along its vertical axis because of the changing stresses in different parts of the fold. Thus in each anticline there will be an upper portion in which the strata in the vicinity of the crest have been in state of tension; and an under portion in which they have been in a state of compression; while in each syncline the same phenomena will be exhibited in reverse order. Where stretching has predominated, the fold will be simply elongated; but in the area of compression, subsidiary plications will be developed and will increase in relative amplitude as their vertical

FIG. 32. *Ideal section through synclinorium of Manx Slates.*



distance from the node or neutral belt of the governing fold increases. With the growth of these interpolated folds, the comparative importance of the governing fold is gradually diminished upwards and downwards, until eventually, in a homogeneous sequence, some member of the subsidiary order is in turn advanced to the first rank, and forms the centre of a new system. Thus in each fold of a complex system there must be a medial plane at which the fold attains its greatest individual development, and above and below which it tends to split up and lose its identity.

In a heterogeneous rock-sequence isoclinally folded, it is evident that the medial plane of the principal folds will occur in the rock-band best adapted lithologically to form master folds under the given stresses; and the folds will therefore decrease in amplitude upwards and downwards from a definite horizon. These are the principles which I believe to have governed the folding of the Manx Slate Series. They are

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illustrated in the above theoretically-constructed diagram of a synclinatorium, which I have taken as the basis of my interpretation of the tectonic structure of the central massif of the Island.

The practical application of this hypothetical diagram is shown in the three transverse sections forming Plate II.

These sections are drawn across the Island at right angles to the strike of the Slate Series, and the centre of the synclinatorium is made manifest in each by the deep infold of Barrule Slate under the highest elevations of the surface. The igneous dykes are omitted, as they are too numerous and too small to show on this scale; and the Dhoon Granite, which appears in Section No. 1, is the only large intrusive mass traversed. Section No. 3 crosses the basin of Lower Carboniferous rocks of the south of the Island, showing their position in regard to the Manx Slates.

These sections will be found to incorporate all the leading facts of the field-evidence as to the structure and general relationship of the sub-divisions of the Slate Series given in the foregoing and subsequent pages.

CHAPTER IV.

DETAILED DESCRIPTION OF THE MANX SLATE
SERIES AND THE ACCOMPANYING IGNEOUS
ROCKS.

INTRODUCTION.

In the general sketch of the Manx Slates contained in the foregoing pages the greater part of the local information in regard to the series and the igneous rocks which traverse it, which was acquired during the prosecution of the survey, has been omitted. It is desirable, however, that this should be placed on record for the assistance of future investigators working in the same field. In the present chapter, therefore, will be given all such topographical details relating to these rocks as have not found place in the preceding chapter, along with the major portion of the information regarding the igneous rocks of the Island. As these details are for the most part based on working notes made on the six-inches-to-the-mile map, many place-names will be mentioned in them which do not appear in the published geological map on the one-inch scale. Such names are denoted by italics.

For convenience of local reference, the area to be described will be divided into three districts:—Northern, comprising sheets 4 to 8 of the six-inch Ordnance Map; Central, comprising six-inch sheets, 9 to 14; and Southern, sheets 15 to 19. These districts will be further subdivided under the separate headings of,—first, the western coast-line of each district; next, its eastern coast-line; and lastly, its interior, keeping generally the order and limits of the six-inch maps, but transgressing this order in favour of the natural physical boundaries in the case of the chief valleys or other similarly well-defined features.

NORTHERN DIVISION.

Western Coast.

On the north-western side of the Island, a tapering prolongation of the low-level drift platform of the north laps the old massif for several miles farther south than on the north-eastern coast, and has evidently once been continuous at least as far southward as Peel. In walking in calm sunny weather on the top of the cliffs between Peel and Ballacarnane, although we find the solid rocks are now exposed down to low tide, we may frequently observe indications of the Pre-glacial limits of the Island, in the sudden ending off, beneath the transparent water, of the rich purple patches of the weed-covered rocks against the delicate green tint which denotes the smooth sandy bottom where the drifts make the foundations of the sea-floor. Near Gob ny Creggan Glassey this line of demarcation draws shoreward and passes gradually from low-water to high-water mark; and from this point northward Glacial and Post-glacial deposits form the whole of the cliff and foreshore (see sections, Figs. 92 & 93, p. 348), but are being rapidly stripped away by the continual encroachment of the sea (p. 13).

Off this part of the coast, as far south as Peel, the Admiralty Chart shows that the sea bottom shelves very gradually, the 10-fathom contour which farther southward lies usually within a few hundred yards of the cliffs, sweeping out here to seaward for a distance of over four miles from the shore. There is, however, one striking break in the uniformity of the floor, where the "*Craig Rock*" of the chart rises suddenly, from a platform having a depth of about six fathoms, to within two fathoms of the surface, at the distance of $1\frac{1}{2}$ miles from the coast near Gob y Deigan. Any evidence which might hereafter be obtainable as to the composition of this rock would be of great interest in view of the problems connected with the age and relations of the Peel Sandstones. If the line of fault which brings in

these beds is prolonged northward beneath the sea, with the direction it possesses on the foreshore at Wills Strand, its course must lie in close proximity to the Craig.

The chief features of the cliff-sections between Gob ny Creggan Glassey and Ballanayre have already been described (pp. 67-69), but there are a few further details respecting them which deserve mention. In coming south, the first exposure of solid rock occurs at the foot of *Glen Beg*, a little ravine cutting back from the cliff across a narrow bench of drift; and it consists of dull black pyritous slate or mudstone, approximating to the Barrule type, containing vermicular markings probably of organic origin, and some curious small oval black phosphatic (?) pebbles or concretions. This material looks promising for graptolites, and though none have yet been found, it might repay further search. Striped slates with occasional grit bands, much contorted, and fractured both horizontally and vertically by planes of movement, and in places reduced to breccia, then occupy the cliff and shore for about a mile, with some alternations of the muddy pyritous slate.

COAST
SOUTH
KIRK
MICHAEL.

At *Glen Thoar*, another short gully cut back from the shore, close to the old 'Camp', marked on the one-inch map, a buried vertical wall of slate, about 30 feet high, is revealed, against which the drift is banked so that the solid feature is obliterated at the surface. This appears to represent a portion of a Pre-glacial buried valley, being probably the north wall of an old water-channel which, like the existing stream, has notched the coast-line in descending to the ancient shore at this point. Within the next 600 yards there are several interrupted strips of intrusive igneous material, from 1 to 3 feet wide, among the slates of the cliff and shore, representing small 'greenstone' dykes of the intermediate type (see p. 300), crushed almost out of recognition. A larger mass of similar intrusive rock, much crushed around the edges and broken by faults, forms the little headland on the northern side of Lady Port, and at least six more intrusions of smaller size are passed between this place and Gob y Deigan, 800 yards farther southward.

The promontory of Gob y Deigan, again, is composed of a sheared or faulted mass of somewhat basic igneous rock, and from this point southward, to the incoming of the Peel Sandstones, scarcely any section can be found which does not reveal these intrusive dykes in one form or another. Though these dykes, as already stated (p. 68), have clearly been injected after the brecciation, they have been implicated in the later movements to such an extent that it is rarely possible to trace them for more than a few yards continuously, or to distinguish which of successive parallel strips are separate dykes and which are repetitions by folding. The thinner strips are frequently crushed throughout into a palish chloritic schist in which no trace of igneous structure is preserved, while, when the dyke is thicker, its edges alone are sometimes frayed out, as shown in Fig. 33 on the following page.

GOB Y
DEIGAN

The course of the similar dykes in most parts of the Island usually coincides with the strike of the dominant cleavage, i.e., E.N.E. to W.S.W.; but in this district, while a few follow this direction, the majority run at about right angles to it, or N.N.W. to S.S.E. In sections farther south there are indications that the dykes which exhibit the N.N.W. strike may be of somewhat newer date than those striking with the cleavage; but no evidence of this kind seems forthcoming in the above-described examples.

On the shore of the bay south of Gob y Deigan (*Lhiannag* of the 6-inch map) some crumpled patches of pale green slate are revealed, among darker striped slates of the usual type. Similar small outcrops of pale slate of greenish tint will be subsequently noticed in other parts of the Island. It is possible that these may denote a definite horizon; but no evidence has yet been found to connect these widely separated and impersistent outcrops. They may, indeed, indicate only the final stage in the crushing and disintegration of igneous material;

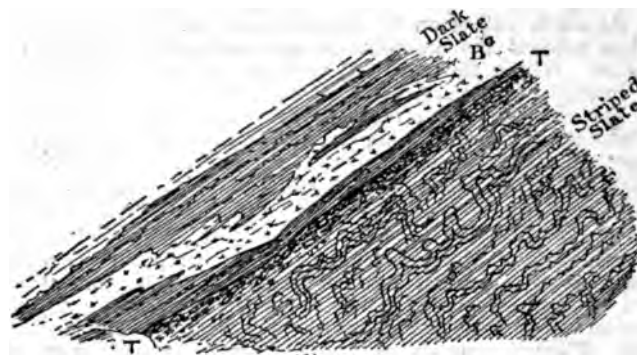
and the appearance of laminar bedding which they present may be merely secondary fluxion-stripe of the character illustrated in Fig. 27, p. 82.

North of Ballanayre Strand, in the grand sections of the crush-conglomerate already described (pp. 68-9), double cleavage-structure is in places admirably displayed, schistose planes dipping N.N.W. at 40° being crossed by a second fissility in the same direction but at a much lower angle, varying from nearly flat to 15°. Crushed quartz-veins of about the same age as the dykes, or a little later, are very abundant in these sections.

In the finer-grained bands of the supposed Niarbyl Flags of Ballanayre Strand (p. 38, and Fig. 13), there is a rather strongly marked cleavage, dipping N. 10 W. at 20°, and an attempt has been made on a small scale to open a slate quarry in these beds at the northern corner of the bay. The faults which cut the flags in this vicinity seem to be later than all the crushing.

Certain pale dykes, of the intermediate type (p. 100), which traverse the unbroken slates as well as the crush-conglomerate, between Ballanayre

FIG. 33. *Section at base of cliff on south side of Gob y Deigan.*



B°. Crushed and torn greenstone dyke traversed by quartz strings. Thickness about 4 feet.

T. Thrust-plane, with brecciated slate, passing into crumpled slate below.

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and *Gob y Skeddun*, appear to be folded (see Fig. 14, p. 69), besides being frayed out at the margins and dislocated at short intervals. The severity of the later crushing in this locality is probably due to the proximity of the hard mass of diabase seen in the cliff in several places between *Gob y Skeddun* and Wills Strand, the less resistant strata having been buckled up against it. This mass is itself torn by faults and much altered around the margin, while its interior, which is well displayed for about 100 yards in the headland north of Wills Strand, is uncrushed and so petrographically distinct from its edges that it has been questioned whether there may not here be a combination of intrusions of different date, though, so far as can be judged from the field evidence, there is a gradual passage from the crushed to the uncrushed rock-types.

A thin strip of somewhat decomposed slate intervenes on the north shore of Wills Strand between the diabase above described and the fault which brings in the Peel Sandstone. Further details of this locality and of the sandstone cliffs to the southward will be found in Chapter VI. (p. 272).

Eastern Coast of the Northern Area.

On the north-eastern coast, the solid rocks set in suddenly near Ramsey, 200 yards south of the ravine at Ballure, in an interesting section elsewhere described and figured (see p. 346, Fig. 91). Here, even more strikingly than on the western coast, the outline of the Pre-glacial cliff may still be traced. For over half a mile the recent rock-shelf extends only 40 or 50 yards outward from the cliff, and the remainder of the broad foreshore is underlain by red boulder-clay, revealed only when the sandy beach is swept aside by the waves. This boulder-clay evidently hides a Pre-glacial tidal platform, of somewhat lower level than that of to-day; it extends at low tide from Ramsey to Port Lewaigue, and though there interrupted by the steep rocky shore of Tableland Point (Gob ny Rona of the revised Ordnance Map), is seen again at low tide on the foreshore of Port e Myllin, 600 yards farther east.

With the exception of the narrow faulted strip of crush-conglomerate mentioned on a previous page (p. 66), the solid rocks, for the first 600 or 700 yards, consist of ferruginous dark blue or blackish slates of the Barrule type, exhibiting a faint much-disturbed colour-banding where washed smooth by the sea, but with the cleavage-structure dominant on subaerially weathered surfaces. This slate has been quarried on a small scale in the cliff 500 yards west of Port Lewaigue. Thin crushed strips of an intrusive 'greenstone' are visible here and there on the fore-shore about 400 yards from the commencement of the rock-sections; and in approaching Port Lewaigue a larger belt of similar but more massive greenstone is encountered, apparently bounded on the north by a strike-fault, and on the south merging, through fissile schist, into pale smooth greenish slate resembling that noticed at Ballanayre (p. 319). Associated with this pale slate are some narrow strips, a foot or less in width, of a pale greenish sheared igneous rock, presenting a somewhat vesicular aspect, from the decomposition of a porphyritic constituent which has been dragged out into lenticles (see p. 319). The same combination of rocks is again seen on the eastern side of Port Lewaigue, where it is twice or thrice repeated by folding or faulting within the space of 150 yards; while at Tableland Point the massive greenstone is repeated, and forms the whole of the low rocky cliff.

The Carrick, an isolated reef 400 yards N.W. of Tableland Point, submerged at high tide, but at low water having an extent of 50 yards by about 35 yards, is composed throughout of a massive tough palish grey rock weathering with a brownish surface, which possesses no distinctive character to denote its origin even when sliced and examined microscopically, but is probably an igneous intrusion decomposed and rendered structureless by shearing.

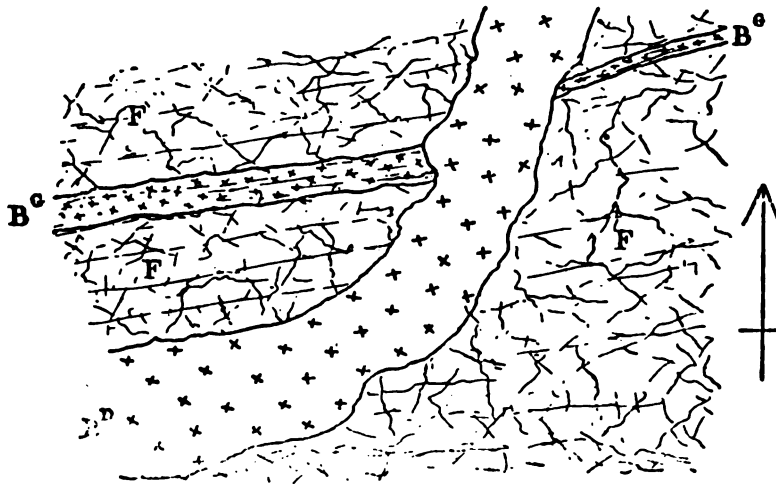
The cliffs on the eastern side of Tableland Point exhibit several fault-like fractures parallel to the cleavage, which seem to be the prolongation of those seen on the shores of Port Lewaigue. The rocks are greatly shattered, confused, and traversed by quartz-veins in the vicinity of these planes; but strips of the pale slate, and of the associated vesicular-looking dyke, are again recognisable, along with a broader 'greenstone' dyke which appears to have been sharply folded. On entering the little bay of Port e Myllin from the west, we find dark striped slates, beautifully crumpled and crossed by the dominant shear-cleavage, with small pyritous nodules lying in the shear-planes. These slates are traversed by a dyke of basic rock 3 feet wide, which is scarcely at all sheared, and seems to be of newer date than the majority of the intrusions (see p. 320). Eighty yards farther south, a sharp boundary, probably a fault or thrust-plane, brings in a pale felspathic mass of peculiar character, which may originally have been an elvan, but is now sheared beyond recognition. This extends in the low cliff for 150 yards, into the middle of the bay, and there suddenly terminates. On the foreshore the felsitic mass is traversed, as shown in the following figure, by narrow later basic intrusions of two different ages, one of which has participated in the shearing and has been reduced to a schist, while

the other is an unsheared dyke of the newer greenstone type, like that above described. This exposure will be further discussed in Chapter VIII. (p. 319).

On the eastern side of Port e Myllin we reach the edge of a tract occupied by a firmer type of slaty rock, composed of alternating bands of dark blue argillaceous and pale grey somewhat arenaceous material, with thin layers of hard grit at frequent intervals. At first sight these rocks seem to be regularly bedded, with a steady dip of about 45° towards N. 15 W.; but on nearer inspection the true structure is found to be a closely packed series of isoclinal folds, partly obscured by fluxion-planes parallel to the limbs, and partly by a later strain-slip cleavage having the same strike as the strata but dipping at a lower angle.

FIG. 34. *Ground-plan of portion of foreshore in Port e Myllin, near Ramsey, showing igneous complex.*

14 feet × 10 feet.



B^D. 'Newer Greenstone' dyke, yellowish-brown in colour, uncrushed, 4 feet thick; traversing F and intersecting B.

B^O. 'Older Greenstone' dyke, spotted yellowish-green, 3 to 6 inches thick, traversing F; greatly sheared and pinched, especially to the eastward of B^D.

F. Crushed felsitic mass, pale greenish-gray colour, intensely sheared and full of criss-cross quartz-strings.

These banded slates are apparently the passage beds between the Barrule Slates and the Agneash Grits, and they extend, with certain variations to be noted below, from Port e Myllin to Maughold Head, a distance of 1½ miles, being well displayed in the cliffs and also in the craggy ground above, where they have been rather extensively quarried. In the first mile of this tract dykes are exceptionally rare, and those which do occur are small and featureless and do not call for special comment. There is an old lead trial at *Gob Ago*, the eastern boundary of Port e Myllin, on which large sums of money were expended without result (see p. 549).

In approaching the rock-pinnacle of Stack Mooar, half a mile east of *Gob Ago*, the slates become more sandy and flaggy, and much interpenetrated by quartz-veins. Just before reaching the Stack, a massive band of grit or

NORTHERN DISTRICT: EAST COAST.

quartzite, 6 feet thick, is encountered, and is probably seen again, on the same strike, in a field above the cliff, opposite Ballaterson West, south of the slate quarries; but, as usual with beds of this character, its continuity between these places is doubtful.

The Stack is separated from the cliff by a prolongation of the Maughold **MAUGHOLD** hematite lode, which in this locality is a conspicuous mass of vein-stuff **HEAD**. (quartz, disturbed slate, fault-breccia, etc., with cavities containing hematite but not in profitable quantity) in places 40 feet wide, striking nearly N.W., and inclined 75° towards N.E. As a surface-exhibition of a mineral lode, this section is second only in attractiveness to that at Bradda Head in the south-west of the Island (p. 540).

The breadth and character of this lode might be taken to imply the presence of an important fault; yet it seems to be without effect upon the stratigraphy, except that to the eastward the slates again become, for a space, somewhat less sandy. The vividly striped slates which occupy the cliff 200 to 300 yards farther east have been so welded together by the shearing they have undergone, that they can be raised in large fibrous blocks, with faces determined mainly by the strain-slip cleavages; and in these rocks some quarrying has been done on the foreshore. In this vicinity, the first of a set of microgranitic dykes is seen in the cliff:—in aspect, a light-coloured close-textured band, 3 to 5 feet thick, scarcely distinguishable from quartzite, agreeing in strike and dip with the dominant cleavage- and bedding-planes. A second example—or possibly the first repeated, since the cliff is intersected at intervals by fractures which may be overthrusts or strike-faults—is exposed 450 yards farther east; and others, of greater breadth, between 200 and 300 yards to the southward of Cor Stack. The most typical dyke of the group, however, is an example 12 feet in thickness, revealed in *Gob ny Skey*, 800 yards south of Cor Stack and close to the extremity of Maughold Head. The general petrographical description of these dykes will be found on p. 314; they are characterised by the presence of small porphyritic grains of bluish quartz in a ground-mass of minute microgranite; and from their connection with others farther south we know them to be offshoots from the Dhoon Granite.

Cor Stack is another rock-pinnacle resulting from the scour of the sea upon the crushed rock in line of fracture which in this case strikes N. 10 W. These outstanding rock-masses are common on every part of the eastern coast, sometimes still united to the cliff by a tunnelled neck, and sometimes completely separated from it. In many instances their development appears to date back to the period of the Raised Beach. On the western coast they are less numerous.

Between Maughold Head and Clay Head, joints and fractures wide enough to contain vein-stuff and fault-breccia are frequently stained deeply by hematite, the discoloration sometimes extending irregularly a little way into the adjacent slates, and in several places trial adits have been driven along them in search of this iron ore, sometimes with some measure of success (pp. 540–1). This peculiarity appears to be confined to the north-eastern portion of the Island. It has, with reason, been suggested,¹ from the conditions of occurrence of hematite among the Skiddaw Slates of the Lake District, that New Red rocks have once overlapped upon the Manx Slates in this area; and the subsequent discovery of Triassic and Permian strata beneath the northern plain of the Island has lent strength to the supposition (see Chap. VII.).

The thin grit-bands, which reappear in greater number among the strongly striped slates between Cor Stack and *Gob ny Skey*,² are extraordinarily

¹ See chapter on Geology in Jenkinson's Practical Guide to the Isle of Man, Lond., 1874.

² It may here be noted that the shore may be reached by a rather difficult path near Stack Mooar, giving access, at low water, to the rugged coast for some distance eastward and westward; but between Cor Stack and Maughold Head the cliffs are practically inaccessible except by boat in favourable weather.

crumpled upon themselves, the tremendous inpacking and foreshortening which the rocks have undergone being thereby beautifully demonstrated. Under such conditions, the estimate which has been made of their original thickness by calculation from the dip and breadth of outcrop is, of course, without value.¹

In *Traie Curn*, the little beach between *Gob ny Skey* and *Gob ny Strona* the most easterly point of the headland, the crumpling of the rocks passes in limited patches into true brecciation, though not quite of the 'crush-conglomerate' type. The structure is no doubt due to the proximity of the *Agneash Grits*, which occupy the upper portion of the high cliff on the southern side of the recess, while the lower part is composed of grey striped flags with thin layers of grit or quartzite. Even although thus exposed in a great cliff-section, the complicated folding renders the exact character of this junction doubtful, but we may suspect that a block of the plicated grit has been broken from the main mass and overthrust upon the flags.

A vein of fault-breccia, stained with hematite, strikes into the cliff S. by W. across *Traie Curn*, but has not been identified on the opposite side of the headland. In *Traie ny Foillan*, on the southern side of *Gob ny Strona*, indications of copper were found in a small fracture partly filled with dolomite like many of the crevices in this neighbourhood, and a level has been driven along it north-westward into the cliff (see p. 548).

A few small crushed strips of the 'older greenstone' type of dyke occur in the sections between *Traie Curn* and *Traie ny Foillan*, which may possibly be repeated exposures of the same intrusion.

At *Dhynane*, of the six-inch Ordnance map,² a small inlet 500 yards west of *Gob ny Strona*, we encounter the most northerly example of an olivine-dolerite intrusion on the coast. This type, constituting the newest dyke-rocks of the Island, is supposed to be of Tertiary age (see p. 327). The dyke is in places three feet wide, but shows a tendency, frequent in these dykes, to split into branches. Though a comparatively fresh and sound rock on the beach, it appears to have been decomposed in the cliff to a brown earth, which has been mined, along with the adjacent stained and rotten slate, as amber by means of a level (see p. 556).

Wherever seen, with the rarest exceptions, these olivine-dolerite dykes strike from points between south and east to points between north and west, their average direction being north-westerly (see List, p. 329). Hence their course cuts that of the Pre-Carboniferous greenstones almost at right angles; and cases of the intersection of the older by the newer dykes are not unusual. An example of this relationship is afforded in the low cliff bordering *Dhynane* on the west, where the dolerite cuts a dyke, three feet in width, of the older type. One hundred yards farther south another olivine-dolerite intrusion, similar to the last, is exposed on the foreshore. Between this place and Port Mooar the rocks (*Lonan Flags*) assume the flaggy character which prevails thenceforward along the whole of the eastern coast of the Island. They consist of thinly laminated grey and blue slate and fine arenaceous mudstone in places containing nodules, with occasional thicker bands of more sandy character.

The cliff-sections in this neighbourhood touch the belt of alteration described in the last chapter, and we consequently find that thin slaty layers between harder bands are frequently speckled with minute secondary minerals, apparently the result of dynamo-metamorphism (see p. 109). In this vicinity, also, we cross the structural anticline, and the hitherto dominant north-north-westerly dips of the combined bedding and cleavage give place, after some vacillation, to the south-south-easterly dips of the opposite side of the axis. In the transitional belt the dominant cleavages, though very irregular and complicated by faint cross-fissility, are frequently flat or nearly so; and the bedding planes also often assume a comparatively

¹ See Bolton, Rep. British Assoc., 1893, p. 770.

² According to information gathered from the miners, this name is affixed to the wrong inlet on the six-inch map: *Dhynane*, as known to the miners, is 200 yards farther south, where the "*Dhynane level*" enters the cliff.

low dip, though, as described and figured in the previous chapter (p. 32, Fig. 2), this appears, in some places, to be due to the presence of recumbent folds.

The foreshore between Dhyrnane and Port Mooar is cut by several approximately parallel north-west or north-north-west fractures, filled with breccia and vein-stuff, including calcite, dolomite, chalybite, hematite, quartz, etc. The largest of these constitutes the Dyrnane Lode, which has been extensively worked for hematite by a level from the shore and a shaft in the field above (see p. 540). Copper-staining was noticed along two of the smaller crevices.

Some of these fractures certainly denote faulting, as they displace a set of the older greenstone dykes, five or more in number, which traverse the broad foreshore to the eastward of Port Mooar in a direction nearly at right angles to the fractures. The interruption to the westerly inland course of the grits of Maughold Head, already commented on, may be caused by the cumulative effect of these faults, or by a master-fault concealed in Port Mooar, of which these may be the concomitants. However, no marked stratigraphical effect has been detected in the coast sections, where there is no greater change in the character of the rocks than might well be attributed to folding.

In entering Port Mooar from the east, we find a broad rocky foreshore of PORT MOOAR. thickish grey flags with blue slaty partings (Lonan Flags), thrown into a succession of low folds, with gentle dips and boat-shaped crests, and this arrangement is continued on the opposite side of the bay. The intervening space, though dry at low water, is much obscured by boulder clay and seaweed, but enough can be seen to show that it is occupied by folded flags, probably broken by fractures similar to those already described, and traversed at about half-tide level by a small greenstone dyke rendered schistose by pressure.

In the interior of the bay a narrow lining of Raised Beach is preserved, which tapers out southwards, and a little beyond its termination the foreshore reveals an olivine-dolerite dyke, nine feet in width, which accompanies a fissure filled with brecciated rock stained with hematite. No further example of this type of intrusion is known until we reach Laxey Bay, over six miles to the southward.

The thick hard flags constituting this part of the coast are also traversed, on the upper part of the shore, 200 yards south of the olivine-dolerite, by a dyke of rather handsome porphyritic elvan of the Dhoon type, 8 to 12 feet wide, which appears to be pinched out before reaching low water.

Farther southward the folds into which the flags are thrown become more acute, especially in the more thinly bedded rocks, until the planes of stratification stand nearly vertical; and from this we pass to sections in which the limbs of the folds gradually assume the isoclinal tendency towards S.S.E. which characterise the rocks of the eastern flank of the Island.

On the northern approach to Gob ny Garvain, a group of seven or more GOB NY GARVAIN. small sheared dykes (or perhaps a less number folded) of the older greenstone type, striking nearly east and west, is visible in the cliff. The headland itself is traversed by an intrusion of porphyritic microgranite, 8 feet thick, resembling the previously described example. In this locality some of the thinner flags are thickly marked with the 'Palæochorda' worm-castings. Two hundred yards south of Gob ny Garvain, three or more small dykes of greenstone which are exposed on the crest of a broad anticlinal fold of the flags, instead of having the usual E.N.E. course, strike approximately north-westward. Similar instances of divergence of these intrusions from their usual direction while crossing the crests of folds have been observed in other parts of the Island. The dykes of this type rarely exceed 3 feet in thickness, but 550 yards south of Gob ny Garvain there occurs an example having the unusual breadth of 25 feet; it has somewhat baked and altered the flags immediately contiguous to it. In the gully adjacent to this dyke, at the spot marked "*Iron Mine*" on the 6-inch map (Sheet 8), a short level has been driven along one of the iron-stained fractures which occur

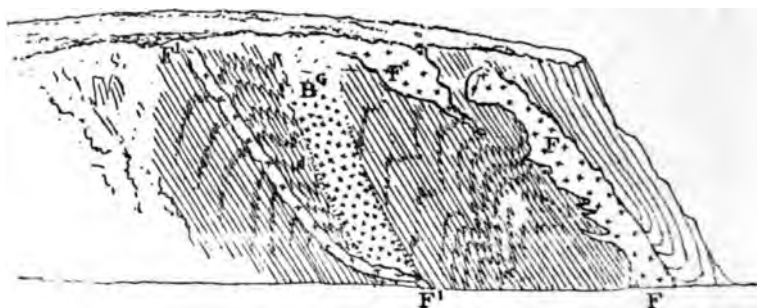
at intervals all along this coast and strike usually to some point between N. and N.W. There is a local reversal of the general dip in this vicinity, the folded slaty flags tending on the whole towards north-west but soon returning to the opposite quarter.

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Two hundred yards farther south, where the coast should round westward towards Traie ny Uainague, a bold dyke of somewhat sheared micro-granite of the Dhoon type, 24 feet in thickness, forms the face of the cliff, hading seaward with the dip of the country rock. Though dislocated in three or more places by faults, this elvan can be traced for 400 yards, to Traie ny Uainague, where in a most interesting section (see Fig. 35) a greenstone intrusion is intersected by a quartz-porphyry apparently associated with the elvan which then strikes inland.

Between Traie ny Uainague and Traie ny Hallsall¹ the constituent strata are chiefly thickish grey flags, occasionally gritty, containing scattered calcareous and siliceous nodules sometimes with cone-in-cone structure in

FIG. 35. *Cliff-section in Lonan Flags on north-eastern side of Traie ny Uainague, Maughold. Height 60 feet.*



B⁰ Much-sheared 'greenstone' dyke, 8 to 12 feet thick.

F. Micro-granite dyke (Dhoon Granite type).

F¹. Porphyritic dyke, probably connected with the micro-granite, intersecting B⁰ at the foot of the cliff.

the outer layer. Among the hard flags there occurs a narrow strip of soft striped blue and grey pencil-slate, bounded by thrusts or faults, which perhaps represents the remnant of a broken infold. In the ground to the southward of this strip the prevalent dips both of bedding and shear-cleavage swing round from S.E. to nearly due eastward.

At the northern corner of Traie ny Hallsall we again find a micro-granite dyke 15 to 20 feet thick, on the shore and in the cliff. This appears to strike inland like the last, but is interfered with westward by one of the north and south fracture-lines. Three-quarters of a mile farther southward, at the extremity of Gob ny Cally, a similar dyke once more emerges at low water mark and strikes westward along the shore. With regard to these exposures, the presumption is strong that what seem to be several separate dykes are in reality the reappearances of one, or at the most of two, dykes (see pp. 129-30) brought about by some method of folding or faulting. It is difficult otherwise to explain the absence of these

¹ Halsall of 6-inch map; Hallsall of 1-inch. I could not find that the name was now in use.

dykes on their line of strike in the interior, especially in the Cornah valley which should intercept the whole of the series traversing the shores between Maughold Head and Traie ny Hallsall, yet where, in spite of the many excellent rock exposures, not one of them is seen.

In the face of the cliff at Traie ny Hallsall the micro-granite is so greatly decomposed, probably from the proximity of the fault, that it can be dug with the spade.

Two hundred yards southward from this recess a dyke of greenstone, of noteworthy thickness and character, rises into the cliff. Its aspect suggests a double intrusion at different dates along the same fissure, one portion being much more sheared than the other, with a well marked parting between them, its total thickness being 12 or 15 feet. This peculiarity may, however, denote that the dyke has been locally duplicated by overthrusting, or that it has originally consisted of two parallel branches, one of which has been more severely crushed than the other. In close proximity to this dyke, a level known as the *Ballaskeg Mine* has been driven into the cliff along an east and west lode which contained a little copper pyrites (see p. 542).

One hundred yards farther south, another greenstone dyke, 10 feet in width, is seen at the base of the cliff; and some smaller strips, striking nearly north and south, occur between this place and Port Cornah.

On the southern side of Traie ny Hallsall the crumpled grey flags dip southward at angles between 10° and 20°; but in *Gob ny Ow*, the north shoulder of Port Cornah, the structure becomes very complicated, the limbs of the folds plunging steeply eastward at about 70°, with a severe strain-slip cleavage in nearly the same direction but at a much lower angle, viz., about 20°, traversing and partly brecciating them. In the weathered crags above the cliff these intersecting planes give the rock a singular corded aspect.

The nodules which occur in the hard flags at this point have had many new minerals developed in them, and the question arises whether their metamorphism is due to the proximity of the Dhoon Granite, or to the severe dynamic action, or to a combination of both causes (see p. 96.)

Were it not that still closer to the granite, on the westward side of Port Cornah, the flags resume their prevalent south-easterly dip, we might have supposed the disturbance above described to have been in some way caused by the influence of that intrusion. But although earth-movement has undoubtedly taken place later than the intrusion, it is evident, from all the exposures near the contact, that the flags were already packed into folds before the igneous mass burst up among them.

In the little recess 200 yards S.W. of Port Cornah a north and south fracture filled with quartziferous lode-stuff crosses the beach, and has been tested in the cliff for copper by a shaft and levels (see p. 543).

A very tough dyke of dioritic 'greenstone,' 12 feet wide, probably altered somewhat by the granite, of a character likely to be well-adapted for road metal, is seen on the low rocky foreshore on the western side of Port Cornah; and similar though thinner intrusions may be traced at intervals along the base of the dangerous cliffs westward of Gob ny Cally, until we reach the bold pale crag, 700 yards south of the Cornah beach, in which, for the last time on this coast, the micro-granite dykes emerge from the sea and pass up into the cliff. The section at this place is particularly interesting, inasmuch as the micro-granites, two in number, each from 10 to 18 feet in width except where pinched, are seen to intersect and alter the greenstones in such a manner as to suggest that shear-structure had been imparted to the greenstones prior to their contact-alteration by the acid dykes, though the latter have, in turn, themselves been rendered schistose at the margin by post-consolidation movement (see p. 309, and Fig. 36).

Unfortunately the spot is difficult of access, as it cannot be approached from the shore, and to reach it one must descend the steep dip-slope 600 to 700 feet high, by which *Barony Hill* plunges to sea-level. Up this slope the two dykes may be traced, by occasional outcrops, to the brow of the hill, where they are well exposed in some small

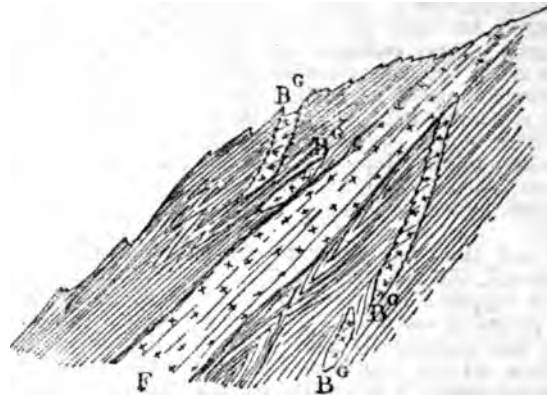
PORT
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openings made in the attempt to quarry them, and thence their course crosses the little moorland to the margin of the Dhoon Granite only 200 or 300 yards distant.

It is noteworthy that in spite of the altitude and extent of the granitic outcrop on the hill so near the cliffs, the granite is not exposed in the coast-section, the two elvans alone being visible there, although the flags in the sections adjacent to it are somewhat baked and altered.

To the southward of the elvans we may observe three further examples of the altered greenstone dykes in the cliff before reaching Dhoon Bay, the largest, 9 feet wide, being 400 yards distant from the more southerly elvan. Strips of similar basic dykes have been traced here and there along the brow of the hill above. Some prominent lenticles of vein-quartz are also conspicuous in the coast-section.

FIG. 36. *Section at foot of cliff under Barony Hill, showing contorted Lonan Flags traversed by dykes of two different ages, viz.:—greenstone (older) and micro-granite (newer).*



B^G. Greatly-sheared greenstone dyke, about 2½ feet thick, broken and faulted by F.

F. Micro-granite dyke (Dhoon type), 6 to 10 feet thick, rendered schistose at the margin by shearing.

DOON BAY. In approaching Dhoon Bay, the thick gritty flags which have prevailed for some distance give place to thin-bedded grey slaty flags. These descend from the hill to the shore in long smooth dip-slopes, with structures suggesting stretching and shearing but rarely crumpling. The little bay owes its origin to parallel lines of fracture running W. 10–20 N., which may indicate considerable faulting. The rocks are softened and stained red and yellow along definite zones in the vicinity of these dislocations, and the same features recur in several places between this recess and Bulgham Bay. The mining trials of the locality are described on p. 528.

The headland to the southward of Dhoon Bay contains several dykes of the 'greenstone' type, which are also numerous in Bulgham Bay and in the headland to the southward, over thirty, ranging in width from 1 to 12 feet, having been counted in three-quarters of a mile of this coast. There is here some proof that these are mostly separate intrusions and not repetitions, inasmuch as in one or two instances they possess individual characters which

could be recognised if the dyke reappeared; thus, an example 8 feet wide, 350 yards south of Dhoo Bay (due east of *Dreem-e-jeskaig* of the 6-inch map), is characterised by the occurrence of small augite crystals in clusters. The outcrops of several of these dykes are prolonged among the high crags which surround Bulgham Bay in a curious cirque-like form, some distance back from the true cliff. Near the summit of these crags, at an altitude of 600 feet, there is a cutting for the high road, wherein some of the dykes are again visible and the broadest has been quarried for road metal. At the extremity of the headland bounding Bulgham Bay on the south, there occurs a greatly sheared pale intrusion, 5 feet thick, which is of felsitic aspect but seems quite different from the Dhoo granite elvans. Among the numerous greenstone intrusions 200 or 300 yards farther south are two or three which are broader and fresher-looking than usual; and these, instead of the ordinary schistose aspect, weather with a massive, rough, vesicular surface from the decay of the porphyritic constituents. This part of the coast furnishes a good example of the tendency of the intrusions to cluster together, leaving intervals in which they are comparatively rare. As a rule they are more abundant among the thin slaty rocks than among the more massive flags and grits, suggesting that they have risen up along the planes of least resistance and have found the latter rocks more difficult to penetrate. Thus, around Bulgham Bay, where the dykes are so numerous, the predominant rocks are of striped flaggy slate much shattered by faults and crush-planes, and in places partly brecciated, and more akin to the rocks of the 'unseparated' tracts than to the typical Lonan Flags, while both to the northward and southward there are areas of thick-bedded greenish grey sandy flags in which the dykes are comparatively rare.

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BAY.

A small abandoned quarry, marking an attempt to find roofing-slate, occurs on the slopes north of Bulgham Bay. The rock in places looks promising for fossils, but my search discovered only obscure "worm-markings."

The description of the coast farther southward is resumed on p. 151.

Interior of the Northern Division.

Starting at the north-western corner of the massif (Sheet 4 of 6-inch map), we find the solid rocks emerge from the drift-plain $\frac{1}{2}$ mile S.W. of the village of Ballaugh, whence, rising steadily, they form the long narrow ridge of Slieau Curn (1,148 feet) between Glen Dhoo and the sea. The predominant rock of this ridge is a greenish-grey striped rather flaggy slate with occasional grit-bands, but on the lower western margin of the hill there is a fairly well-defined belt of flaggy grit, as previously described (see p. 48).

SLIEAU
CURN

The 'unseparated' rocks of this part of the Island exhibit a strongly-marked tendency to splinter in two directions more or less at right angles to each other, apparently as the result of strain-slip cleavage crossing the bedding or an earlier cleavage. This structure gives rise to a short faggoty fracture of the rock and renders it almost useless as a building stone. It is perhaps best developed in the southward prolongation of the ridge, around Slieau Dhoo (in Sheet 7 of 6-inch map), where the walls bounding the moorland, built of material from shallow excavations in the immediate vicinity, are often composed of short billets of stone piled up lengthwise. The dominant dip of the fissility, which sometimes agrees with and sometimes crosses the original bedding, is generally towards north-west, but there is a local reversal to the opposite quarter on the summit of Slieau Curn, apparently due to the influence of a gritty belt.

This ridge is peculiarly free from drift, and the solid rocks are notched in places by dry stream-cut gullies, in positions where it is impossible that any water could flow under present conditions. These phenomena are discussed and illustrated in Chapter IX. (p. 363, fig. 101). In all this region there is a striking rarity of igneous intrusions.

Glen Dhoo, the short straight valley deeply trenching the hill-chain due south of Ballaugh, is more interesting to the physiographer and glacialist

than to the student of the solid geology, as its bottom is chiefly filled with gravel and rubbly drift. There are however some rock-exposures deserving mention in the craggy slopes around its coombe-like head (in Sheet 7), where the manner in which the highly contorted greenish-grey gritty flags are cut and sheared by fluxion structures and strain-slip throws considerable light on the production of the matrix of the crush-conglomerate farther east, as shown in Fig. 37. These rocks much resemble the more gritty portion of the Lonan Flags. (See also p. 48.)

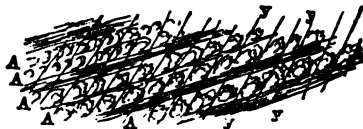
There are good rock exposures towards the head of the picturesque *Glen Shoggle* (which branches away eastward from Glen Dhoo at Ravensdale House), chiefly in pale bluish-grey striped slate of the 'unseparated' type. At the head of the middle fork of this glen the drifts are banked against a buried cliff of slate. In the northern fork there is an old trial adit on a north and south fracture.

On the high moorland ridge between Glen Dhoo and Sulby Glen the rock, though everywhere near the surface, is usually covered with rubble, and the exposures are few and unimportant until we reach the bold

FIG. 37. *Section of grits and slates, showing torsion; in crag on hillside S.E. of Glendhoo Farm, in Glen Dhoo, Ballaugh.*

(From Quart. Journ. Geol. Soc. vol. li.)

Length, about 2 feet.



A, A, A. Grit bands in sheared slates, broken by strain-slip (y—y) and each segment partly turned on its axis.

northern slope descending to the drift plain. In the lower part of this slope about one mile eastward of Ballaugh, there are several quarries in compact striped blue slate approximating to the Barrule type, one of which seems to have been a trial for roofing slate. The later cleavage is nearly vertical, but apparently before this structure was developed the rock was welded by an earlier fluxion-movement parallel to the broadly-folded bedding planes. From the combined effect of the two structures, the slate has a fibrous texture, especially in the trough of the folds, and lifts in long firm beam-like blocks; and on this account the more northerly quarry was at one time much resorted to for lintels, gate-posts, etc. A single slab of slate, 24 feet long by 3 feet wide, which bridges the stream at *Ballacrosha* near Ballaugh, has probably been obtained from this quarry. At Spanish Head in the south of the Island the slate possesses the same peculiarity in a still higher degree (see p. 174). These rocks if prolonged on the line of strike should continue into the cape-like termination of the ridge at Gob y Volley, overlooking the mouth of Sulby Glen, but the predominant strata at this point are of a more sandy and flaggy type with gritty intercalations, the folding of which is well shown in a roadside quarry and in the crags rising above it. Traces of small greenstone intrusions were noticed in three places near the eastern crest of the ridge.

In the vicinity of the gritty beds in this neighbourhood there is a tendency of the dominant bedding-planes to swing over locally to the south-eastward, although the prevalent dip is to the opposite direction. The grits have been found to possess a similar influence on adjacent slaty rocks in many other parts of the Island where the dips are high. The local reversal in such cases probably betokens that the rocks immediately under

OB Y
OLLA Y.

the shelter of the grit-masses yielded less readily than elsewhere to the compressive force which established the isoclinal arrangement of the folded strata.

On entering Sulby Glen we find for the first two miles scarcely any **SULBY** rock-exposures in the river itself, but fine sections in the high craggy walls **GLEN.** of the valley on either side. In these the zone of crush-conglomerate is magnificently exposed, flanked on the west by highly contorted grits and on the east chiefly by Barrule Slates. To the account already given of these sections (pp. 60-5), it will now only be needful to add a few points of detail not previously described.

The greenstone dyke which cuts the crush-conglomerate in the section near the *Cluggid*, shown in Fig. 7 (p. 61), probably crosses to the western side of the valley a little farther south, as an intrusive dyke of similar character is visible among the breccias three-quarters of a mile higher up the valley, 200 yards northward of the cascade descending from Killabraggah, where it has been quarried for road-metal. Another exposure of intrusive greenstone occurs $1\frac{1}{2}$ miles south of Killabraggah, in the crush-conglomerate at the craggy shoulder above the junction of the streams north-east of Druidale farmstead. These outcrops are the more likely to represent one and the same intrusion since dykes are comparatively rare in Sulby Glen and in the country to the westward, though to the eastward there is a belt in which they are very common.

The unnamed eastern tributary of the Sulby which drains the depression between Slieau Monagh and Snaefell, flowing past Block Eary, traverses the last-mentioned belt of intrusions, its bed containing small exposures of some interesting varieties of igneous material. Within 30 yards of its junction with the Sulby, and again in the bed of that river above the junction, we encounter a hard close-grained band six feet wide, which is probably a sheared dyke. In the same neighbourhood, on the northern side of the ravine, are some extensive old slate-trials exhibiting excellent sections of the Barrule Slates (see p. 561).

Between the two larger of these quarries, the Block Eary stream crosses a narrow strip of crush-conglomerate, apparently at the margin of the Barrule Slates; and above this, it flows mainly over firm striped flaggy slate with sandy intercalations until near its source on the northern shoulder of Snaefell, where it trenches for a short distance upon the principal zone of the Barrule Slates.

Nine hundred yards above its junction with the Sulby, or 100 yards above the *Waterfall* marked on the six-inch map, we find the stream-bed occupied by a belt of pale splintery rock, which is probably a felsitic dyke but is so greatly crushed and decomposed that its igneous structure is no longer apparent even to microscopic examination (see p. 323). Between 400 and 750 yards farther east, four or more basic dykes cross the stream, the second of which, 200 yards due west of Block Eary farmstead, is the beautiful example of 'actinolite trap' described petrographically in Chapter VIII. p. 309, while two others seem to be of the later less altered 'diabase' type.

Traces of these intrusive greenstones are also visible at several points in the bed of the little feeder descending the hill-side west of Block Eary. Two old trial-adits penetrate north-west and south-east into the hill from the valley near this place, on a fracture which is supposed to be the prolongation of the Snaefell Lode (p. 527). Higher up the stream, two minor examples of sheared and altered greenstones are encountered; and then, 500 yards E.S.E. from Block Eary, we reach a more important dyke, with an outcrop many yards in width, of pale crushed microgranite, probably one of the elvans from the Foxdale Granite like the great dyke at Crosby. The south-easterly border of this dyke has somewhat the aspect of a line of a fault or overthrust, but this may be due simply to the crushing of the slates against this massive bed. Immediately above it, the character of the country rock changes, as previously mentioned, from thin flags with grit bands, to dark blue lustrous Barrule Slate, somewhat altered, and interpenetrated by many quartz-veins.

In the three short tributaries of the Sulby to the southward of and parallel to the Block Eary stream, between Ballaskella and *Tholt-e-Will*, the exposures, so far eastward as they extend, resemble those just described, excepting that in the first two the belt of crush-conglomerate close to their junction with the Sulby is broader, probably because of the higher altitude at which they flow. The last of the three, at *Tholt-e-Will* just above its junction with the Sulby, has cut a pleasant little gulch into the Barrule Slate, into which it descends by cascades, probably along faults or thrust-planes. In the higher part of its course numerous greenstone dykes are visible.

The upper reaches of the Sulby basin will be subsequently described (see p. 138).

FAU
TASH OR
INAGH.

Turning now to the high ground to the eastward, sparingly covered with drift, between Sulby Glen and Glen Auldyn, we find among the scattered rock-exposures some sections in the crush-conglomerate which have already been described (see pp. 65-66). Near the summit of Slieau Monagh (Meanagh), a large quartz-vein which crops out in *Creg Bedn* at an elevation of about 1,200 feet, has been glaciated in such a manner as to afford proof that an ice-sheet has moved in a S.S.E. direction over the plateau (see p. 363). Near the head of the stream on the eastern side of Slieau Monagh, a thin band of graphitic schist with beautifully polished planes of shearing, occurring among pyritous dark blue slate, was revealed by the workmen in quarrying stone from the bank for the erection of a fence. Traces of the same mineral have been found near Beary Pairk, six miles farther south (see p. 550). The above-mentioned stream is diverted sharply eastward at Ballaneary to flow through *The Cluggid* (p. 60) to the Sulby, but it probably once continued in its initial N.N.W. direction, and passed down one of the valleys which unite with Narradale at Cronk Sumark. It has been intercepted and diverted by the eastward cutting back of the ravine above the Cluggid. Other high-level feeders of the Sulby afford proof of similar physiographical changes, due to the deep trenching of the lower part of the main glen during the period of elevation (see pp. 6-7), which stimulated the activity of all the short transverse streams falling directly into the trough, and led to their rapid backward transgression. The chief branches of the Sulby seem all to have occupied their present relative positions in Pre-glacial times, but it is not uncommon to find that in re-excavating channels blocked with drift, the streams have here and there missed the old gulleys for a short space, and have cut straight-sided notches in the solid rock adjacent to them, sometimes afterwards abandoning these for the more easily excavated old hollows, and thereby leaving dry notches high above the present stream (see p. 449). A good example of this occurs on the Sulby, opposite to Druidale.

The lower part of Narradale affords a further illustration of Post-glacial change, 400 yards east of Cronk Sumark, where the stream passes from a comparatively open valley with high banks of drift into a little gully in slate at right angles to its former course. The bottom of this gully shows the outcrop of a small dyke of the later olivine-dolerite type, which is probably connected with that already mentioned (p. 59) at Kerroo Moor, 700 yards to the north-eastward, and is similarly intrusive through crush-conglomerate. This is the most westerly point to which these supposed Tertiary intrusions have been traced in the district to the northward of the central valley. The present example is probably a member of the group seen on the eastern coast near Port Moor (p. 127).

KERROO
MOOR.

At Kerroo Moor a rather extensive but unsuccessful mining trial has been made in search of lead, on a north and south lode which was found to intercept one of the olivine-dolerite dykes (see p. 546). Numerous other instances have been noticed in the Island in which these dykes are associated with veins containing small quantities of the metalliferous ores; and the possibility of some connection between them deserves and will receive further consideration (see p. 488). The interesting boss of older greenstone of dioritic type adjacent to the old mine is described on a later page (p. 305).

Continuing along the steep northern edge of the massif (entering Sheet 5 of the six-inch map), we find, at Laurel Mount half a mile east of Kerroo Moor, a deep narrow quarry opened into the hillside for road metal. This appears to be the quarry mentioned by Harkness and Nicholson,¹ who describe it as follows: "The bulk of the rock here is grey hard quartz-rock, with occasional rounded pebbles of quartz embedded therein. The quartz-rock here has a great affinity to the grey rocks of Cornah, which have no distinct stratification. Here, however, black shales occur in the quartz-rock, which dip at a high angle to the north-west." The implication in this description that the "quartz-rock" is of sedimentary origin seems, however, to be erroneous; for although so greatly decomposed and crushed that even the microscope fails to throw much light upon its original condition (see p. 306), it bears a general resemblance to rocks in other exposures which are known to be highly-sheared intrusions; and it may, with some confidence, be regarded as a dyke which, like the rock forming The Carrick in Ramsey Bay (p. 123), has lost its igneous structure. Its extensive development in the face of the quarry appears to be due not so much to its breadth as to its repetition, either by folding or overthrusting. This outcrop may serve as a good example of the problematical kind of rock constantly recurring among the slaty rocks in the Island, which one notes down in mapping as "hard band (dyke ?)" and finds it difficult ever to get further with the description.

At the mouth of Glentramman, 600 yards farther east, are two old quarries, probably slate-trials, in striped blue and grey slate with a faggoty structure like that of Sliean Curn. This material seems to lie at the margin of the zone of crush-conglomerate, without definite evidence for the order of their superposition. Indications of north and south faulting are visible in the bed of the Glen, but the depth and narrowness of the gully have prevented the thorough investigation of the sections.

If we cross the ridge from the head of Glentramman to the feeder draining into Glen Auldyn from Parkneakin, we find small outcrops of a palish sheared igneous rock, probably of the 'intermediate' type (p. 300), in the stream-bed 500 yards east of the Parkneakin ruined farmstead, and again in several places lower down, near an old mining trial, among crush-conglomerate, and also on the adjacent plateau, 250 yards N.N.W. of Skyhill farm. Farther south, on the steep slopes descending into Glen Auldyn, small exposures of dykes of other types occur, including mica-trap in the zigzag road 900 yards S. of Skyhill, and diorite in a small old quarry by the roadside in the bottom of the Auldyn valley, 100 yards S. of the sharp easterly bend in the river. Higher up the Glen, two dykes are visible in the bed of a little feeder joining the eastern side of the river just below the most southerly slate trials; the lower, probably a mica-trap, not more than 3 feet wide; and the upper, close to the moorland fence, a sheared palish rock, 10 to 15 feet broad, of the doubtful 'intermediate' group. It is impossible to show these scattered strips of dykes on the one-inch map, and wearisome to describe them. The exposures are usually so limited, and the characters of the rock so obscure, that even where the igneous origin is determinable at all, it is made apparent only by close investigation.

The slate-trial just mentioned is one of an extensive series in the Glen, on which much money must have been spent. The rock in this vicinity is strongly striped blue slate with occasional grit bands, dipping N.N.W. at high angles, and cleaved in the same direction at lower but variable angles. Towards the head of the Glen, a much folded belt of thick-bedded quartz-veined grits is seen among these rocks for a short space. The thin slaty partings of these grits are speckled with small alteration-crystals (see p. 109).

Lower down the Auldyn valley, the gritty characters disappear and the prevalent rock is dark blue ferruginous slate, with the homogeneous aspect

¹ Quart. Journ. Geol. Soc., vol. xxii., p. 489.

characteristic of the Barrule Slate, which is continued northward until the crush-conglomerate sets in under Sky Hill.

The little streams, unnamed on the map, which drain the north slope of North Barrule and unite to discharge into Glen Auldyn at Balleigheragh, flow chiefly over firm strongly striped slate with grit bands, of the 'unseparated' type, resembling that of Maughold Head, in which autoclastic structure is visible in places. The westerly fork, known locally as *Glen Crinn*, reveals several 'greenstone' dykes in the stream-bed, especially in its upper reaches, where one or two of the intrusions are of rather unusual character and seem to be more nearly allied to the acid than to the basic group. In *Braid Foss*, the easterly branch, there is much obscure faulting and crushing, especially in the vicinity of an old lead mine (see p. 545). The upper part of the main arm of this stream follows the north-west course of a branching olivine-dolerite dyke, 8 feet wide in places, which is well exposed in the walls and bed of the little cañon for about 200 yards, and then strikes across into the parallel gully 100 yards farther west, where it is seen in the mining excavation. It can also be traced in the opposite direction up to the slope below the mountain-road.

On the eastern side of Glen Auldyn, banded slates like those of Maughold Head prevail in the steep slope south of Crossags Farm, giving place to a wedge of thickish grits opposite Claghbane; east of which, as already described, crush-conglomerate is the chief component of the sections.

LUKE
S.

In the upper part of Ballure Glen, above the Ramsey Waterworks Reservoir, several 'greenstone' dykes may, with difficulty, be detected; while on the steep hillside nearly due east of the Reservoir and on the opposite side of the Glen, a small quarry has been opened in a boss of rather fresh-looking diorite, and the same rock is visible in the adjacent mountain road. There seems to be considerable difference of petrological character between this rock and that on the shore at Port Lewaigue, already described (p. 123); otherwise the field evidence suggests that they may be parts of the same intrusion. West of Ballure Glen, and adjacent to the little gully running parallel to the new mountain-road at Park Mooar, a broadish band of pale felspathic material, probably the prolongation of the Port e Myllin mass (p. 124), is seen at intervals for 600 or 700 yards, striking E.N.E.; and a detached strip of like character is poorly exposed, 250 yards farther south, in the cross-road to Dreem-e-Lhergy (between *a* and *n* of *Roan* on Sheet 5 of the six-inch map). In the field on the western side of the road at *Roan* an upfold of coarsish grit, 4 feet thick, crops out for a short distance and is well shown in a small quarry. Immediately to the southward lies the great belt of Barrule Slate, the edge of which has been quarried in a slate-trail near Dreem-e-Lhergy and again half a mile farther to the north-east, on the slope facing the sea at West Folieu. In another quarry at the latter place, 150 yards S.E. of the slate quarry, we find a highly sheared basic dyke, accompanied by pale bluish and greenish lustrous sericitic schist; these appear to be the inland continuation of the rocks seen on the shore at Port Lewaigue, 500 yards distant (see *ante*, p. 123). The adjacent rounded hill-top of Slieau Lewaigue exposes a fine example of crushing and shearing in hard grey gritty flags with thin slaty partings, the teasing out and intermixture of the bands where they lie athwart the direction of movement being very remarkable. A 'doubtful' dyke occurs in the same exposure.

ERIOR
TH OF
K
HAEL.

We return now to the north-western flank of the Island to take up the investigation of a strip of country to the southward of that examined above, comprising those portions of the six-inch sheets 6, 7 and 8 not already described, commencing with the inland tract between Kirk Michael and the northern edge of the Peel Sandstone.

The belt of cleaved flags and grits running S.S.W. from Kirk Michael is exposed in a small quarry where the high-road crosses Glen Mooar, as well as in the adjacent railway-cutting; and in low crags higher up the slope around the farmsteads of Ballacarnane Mooar and Beg, and Skerestel Mooar; and again in a roadside quarry at *Glion Cam*; and in many smaller outcrops. 'Worm-markings' can usually be detected in these flags, which

afford also some interesting structures from the intersection of the bedding and cleavages. Disturbances of the strike of both bedding and cleavage, by which both dips are brought round to north-eastward, occur in many places along the eastern edge of the belt.

Behind the farm-buildings of Skerestel Beg, three quarters of a mile inland, a broadish dyke of mica-trap is visible, but the exposure is poor and weathered. Four hundred yards farther east, amid an area of pale blue sericitic slate of ill-defined characters, a low crag of massive bluish quartzite, weathering very pale, crops up in the corner of a field close to the high-road, on the parish boundary between Michael and German. One might expect that a strong band of this kind would be continuous for some distance, and would be of service in the task of unravelling the structure of the Island; but it disappears immediately in both directions, being barely traceable in the field on the opposite side of the road. From analogous examples in the cliffs, the outcrop probably marks the isolated segment of a broken dome-like fold which has burst into the slates. A somewhat similar rock occurs in the bank of the Glen Mooar stream, three quarters of a mile north-eastward, 400 yards N. of Chester, but the quartzite is there associated with other smaller grit bands among banded slates. A 'greenstone' dyke, 9 feet or more wide, is exposed close by, on both sides of the stream.

In *Glion Cam*, 300 yards S.E. of the high-road, a slaty breccia with the fragmental structure almost obliterated by later cleavage occurs at the highest point in the stream-bed where the solid rock is exposed; and a small 'greenstone' dyke is revealed in the same locality. There is probably much of this slaty breccia farther westward, but the shivery ferruginous rubble into which it weathers usually hides the rock-surface. The exposure of the autoclastic structure in a small quarry near Corvalley, half a mile S.E. of *Glion Cam*, has previously been mentioned (pp. 66-7).

Pale blue sericitic slate, which shatters into lustrous platy *débris* and is associated with occasional gritty layers, predominates in the ridge (extending into 6-inch Sheet 9) between the depression leading into the valley of the Neb and the low country underlain by the Peel Sandstone.

At Knocksharry there is an outcrop of coarse grit, apparently the thinning out of a wedge which expands southward (pp. 48-9); and a mass of sheared basic igneous rock is seen at Creggan Mooar in its vicinity.

At *Cronk y Voddee*, 1½ miles farther eastward (at the S.E. corner of Sheet 6), a boss of sheared and decomposed porphyritic diabase, having affinities with that of the Poortown Quarry (p. 304), has been quarried at the roadside adjoining the Parsonage; and a similar boss, though of different petrological aspect, occurs at Cronkbane, 300 yards to the northward, near an old mining-trail (p. 547). It is difficult to say whether these are originally isolated intrusions, or are dislocated fragments of a once continuous dyke; the smaller shreds seen here and there in the vicinity of the larger masses lend favour to the latter supposition. A less basic rock, apparently of igneous origin and perhaps akin to that at Lhergydho (p. 156), is exposed in a small quarry (Sheet 7) on the hillside 700 yards N.E. of *Cronk y Voddee Chapel* ("St. John's Chapel" of 1-inch map) and 200 yards S. of the milestone ("Castletown 13 m.") on the high-road. In this quarry igneous and sedimentary rocks seem to have been folded and crushed together. Other small outcrops of ill-defined intrusions were noticed 300 yards farther east, and again a mile to the northward, at the head of *Glion Cannell*, east of the high-road. This hillside has been the site of numerous small workings in search of lead, and an attempt has also been made to develop a slate-quarry in the dark blue Barrule Slates which occupy the ridge between the Ramsey high-road and the valley of the Neb.

The physiographical features of this neighbourhood deserve attention. The broad shallow depression through which runs the high-road from Kirk Michael to St. John's has probably owed its origin to a single stream flowing northward, but now gives birth to small streams which run, respectively, northward through Glen Wyllin, westward through Glen Mooar, and southward into the deep valley of the Neb. The

GLEN
WYLLIN A
FERDERS.

Pre-glacial elevation quickened the activity of the shorter westerly and southerly drainage, so that these streams tapped the head of the old basin and divided its waters. Since Glacial times the northerly stream seems to have been gaining ground, having swept the drifts out of Glen Wyllin more rapidly than its rivals have been able to deepen their solid channels, thus increasing the fall northward from the col at Barrowgarra.

The curious dry valley of glacial age which trenches the ridge on the eastern side of Glen Wyllin is described in Chapter IX., p. 365 and Fig. 102.

In Glen Wyllin the rock-exposures are scanty and unimportant until we approach its head in the deep coombe-like glens on the western slopes of the mountains. *Glen Kiark*, the more southerly of its branches, between Sartfell and Slieau Freaghane, is excavated in ferruginous hard dark blue slate with occasional crumpled bands of dark muddy pyritous grit, shown on the map (with some misgiving) as Barrule Slate, and the same firmly welded slate occupies the western slopes of the adjacent mountains. Large slate-trials have been made in this rock in *Glen Kiark* and again on the south-eastern shoulder of Sartfell near the place marked '*Level (Lead Mine)*' on the six-inch map (Sheet 7). The upper part of the glen enters striped slates and sandy flags, of the 'unseparated' type, much crumpled and frilled with transverse shear-cleavage; and rocks of similar type extend thence, over the summits of Sartfell and Slieau Freaghane, to the upper basins of the Neb and Sulby; and indeed, with minor variations, westward up to the main eastern belt of Barrule Slate in Snaefell and Beinn y Phott. In some places pale grey tints prevail, in others blue, but oftener the strata show these colours in thin strongly contrasting alternate layers. Where there is a well-defined cleavage across the bedding, the slate has the 'faggoty' or sometimes pencil-like fracture already described. 'Fluxion-structure,' pseudo-ripple-marking, pulled lenticles, and partial brecciation are of frequent occurrence throughout this tract.

Dykes appear to be rare until we descend into the Sulby basin, but this may be partly because the exposures are not as a rule favourable for the display of the smaller intrusions. In the deep coombe between Slieau Curn and Slieau Freaghane there is an abandoned lead-mine, for an account of which see p. 547.

The wet grassy slopes of the upper part of the Sulby basin above Druidale are usually underlain by drift, the solid rocks being rarely seen except in the stream-courses. The striped flaggy strata are often on the verge of disruption, even where they do not pass over into the actual crush-conglomerate of the sections already described (p. 65). Generally throughout the Island, in descending from the hills into the valleys we find an increasing proportion of gritty material, and this part of the Sulby basin is a case in point. On the western side of the river, a belt of flaggy grit (shown on the one-inch map) is revealed in the beds of the little feeders west of the Druidale farmstead; and again half a mile farther north in the deep gully under *Sharragh Bedn*, where the grits seem to be cut off by a W.N.W.—E.S.E. fault which has attracted some mining exploration. On the eastern side of the river also, thickish grit bands (not shown on the map) are seen in the beds of the two uppermost feeders, 500 to 600 yards from the main stream, nearly on the line of strike of the great zone of crush-conglomerate. In the more northerly of these feeders the grit is associated with bosses or veins of quartz of unusual dimensions, one mass occupying the bed of the stream for several yards.

A general knowledge of the geology of this part of the Island may be gained by scrambling up-stream along the bottom of *Glen Crammag*, down which a tributary of the Sulby flows northward for 1½ miles from the western shoulder of Beinn y Phott. For the first 300 yards after leaving the main river we find the bed of the stream to be composed chiefly of crush-conglomerate, with a fault or crush-plane at its southern margin along which a short trial-adit has been driven. We next cross a wide stretch of banded slates, partly brecciated in places and much cut by fault-like fractures and by quartz-veins. A dyke of 'greenstone,' 6 feet

wide, is found, 750 yards distant from the mouth of the Glen. Then, 150 yards higher up, some pale greenish and bluish beds are seen, recalling those on the shore at Port Lewaigue (p. 123); and close by, a pale felsitic trap, 9 feet wide, probably belonging to the microgranite group. In the next 600 yards several small dykes of 'greenstone' are visible, traversing strongly-striped and somewhat altered slates with thin gritty bands; and then another example of the pale trap is met with, and two others 300 yards farther up, which we recognise as microgranites like that of Block Eary, probably emanating from the Foxdale granite (see p. 317); while between the pale traps are other small 'greenstone' intrusions. Whether these dykes be repetitions by folding or faulting it is not possible to determine, but the whole group seems to be prolonged into the next glen eastward, which carries the drainage from the western slope of Snaefell and opens into the Sulby only 300 yards below the mouth of *Glen Crammag*. In this easterly glen the dykes begin to be seen 400 yards above its mouth, and recur at short intervals throughout the next half mile, up to the sharp elbow east of Lhergyrhenny where there appears to be some faulting, above which for over a mile dykes are exceedingly rare. The slates in the lower part of this glen possess the same characters as in *Glen Crammag*, but the section is carried back farther eastward. Above the elbow just mentioned, we find beautifully striped slaty and gritty flags much veined with quartz, affording excellent studies in partial brecciation and double cleavage (see Fig. 24, p. 79). Then, near an old lead-mine, a narrow belt of the dark blue sericitic Barrule slate is crossed, like that forming the greater part of Snaefell and Beinn y Phott. This slate has been intensely sheared and cross-cleaved. It probably lies in a synclinal trough, which expands upwards into the above-mentioned hills; and this suggestion is borne out by the reappearance higher up the stream of striped slates with gritty alternations, like those seen lower down. From 800 to 1,100 yards above the old mine, several small decomposed basic dykes are poorly exposed in the stream-bed, and the question arises whether these may, like the sedimentary strata, be repetitions of those revealed on the opposite side of the infold. But they are apparently unaccompanied by the acid dykes, and present some differences of petrographical character which seem to distinguish them from the previous set. In common with the slates, the dykes in this quarter have undergone considerable alteration, amounting in the case of the intrusive material almost to re-crystallisation. This metamorphism may be still better studied half a mile farther south, across the col, in the little glen draining into the Baldwin River, where an altered 'greenstone' intrusion occurs in a larger and less weathered exposure in a low crag on the lower slope of the mountain, 100 yards west of the stream. There are also some striking illustrations of alteration in the slates themselves on the western and northern sides of Snaefell, in the cuttings for the recently-laid tramway to the summit, where, as described on p. 110, the sections showed, in places, the sporadic development of garnets in the slate adjacent to hard bands. A broad decomposed dyke, in which actinolite has once been abundant, was exposed in a cutting on the line about 1,400 yards W.S.W. of the summit, and another of smaller size in another cutting 150 yards N.E. of that spot. In several places nearer the mountain top, up to the highest level attained by the tram-line (about 2,000 feet), the excavations revealed good examples of glacially striated rock-surfaces (see p. 361). On the N.E. shoulder of the mountain (at the western border of Sheet 8) a small quarry has been recently opened in a dyke-like mass of actinolitic 'greenstone,' 18 feet wide, which may be the same rock as that of the tramway section, in a less weathered condition.

Following the grassy mountain ridge of Barrule Slate north-eastward from Snaefell (p. 50), we find a few traces of intrusions, both of the acid and basic types, in the form of scattered blocks marking the proximity of outcrops, on both sides of Clagh Ouyre; and a small dyke of microgranite, like that of Block Eary, is scantily revealed at the side of the new mountain-road due north from the cairn on the summit of Clagh Ouyre, and again in the bed of a gully in the same vicinity, 200 yards below the road. Along the crest of the ridge the dark blue slate has an almost continuous outcrop in

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low scars, much seamed with quartz-veins (containing some chlorite and mica), while south-eastward the slopes break away into lines of steeper crags overlooking the Cornah Valley. In the lower range of these crags, on the southern side of North Barrule north-east of Park Lewellyn farmstead, a large mass of igneous material, many yards in width, is exposed in a succession of lens-like bosses. The rock is of the 'doubtful' type, pale greyish, close-grained and splintery, seemingly intermediate between the greenstones and the microgranites. It is, however, too much crushed and altered to yield much information even under the microscope (see p. 317).

Higher up the hill we find traces of some small dykes of greenstone 1 to 3 feet wide, which are of somewhat unusual aspect, being rather coarsely porphyritic. The glacial striations occurring on the crest of the ridge are referred to on p. 361.

The bold crags in which North Barrule terminates abruptly eastward afford a good opportunity for studying the internal structure of the ridge. A series of roughly parallel planes dipping N.N.W.—i.e., in the same direction as the cleavage—splits up the Barrule Slates into tabular or wedge-shaped blocks resting one upon another, not unlike ordinary bedding, and giving the appearance, at a distance, of true stratification. When more closely examined we find that the rock near these planes invariably shows evidence of crushing and sliding, and that the actual bedding is only occasionally parallel to them. They appear, in fact, to be small overthrusts by which the previously folded slate has been split into thick slabs and piled or packed together. In the process of weathering these divisional planes give rise to ledge-like features simulating stratification dipping into the hill.

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Descending to the foot of the slope, we find, in a field adjoining the old mountain-road 500 yards north-west of *Cardle Veg*, in the thinly drift-covered ground a group of large blocks of massive quartz-veined grit, evidently denoting an outcrop of this character. This has been mapped as the northern edge of the Agneash Grits, but there is a strong possibility that it may represent the reappearance of the isolated band of quartzite seen on the east coast at Stack Moor (p. 124). The ground to the eastward is cultivated, with no rock exposures for over a mile excepting in the gutter of a little stream running to Cornah from Margher-e-kew, where there are scanty outcrops of flaggy striped slate. Between Ballasaig and Magher-e-breck, however, we find much rocky ground, made up in part of flaggy grits, and in part of strongly striped slate or slaty flags in which the dark argillaceous bands are speckled with alteration-products.

At Magher-e-breck a north and south lode has been mined for hematite with fair result (p. 541). A small quarry 250 yards N.N.E. of the farmstead at this place has been opened on a massive band of coarse grit and hematite-stained vein-quartz, apparently thrust in among shaken and altered slates.

It is worth noting that on the glacially-rounded rock-face to the northward of this quarry, two highly burnished fragments of vein-quartz, one-eighth to three-eighths of an inch in diameter, were tightly impressed and fixed in a singular manner upon the firm surface of the slate. The anomalous condition and position of these fragments did not seem referable to glacial agency, and yet were otherwise difficult to account for; unless the action of the lightning upon the crag seems a possible explanation.

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To the southward of the supposed Agneash Grits, the ground up to the coast on the east and the deep valley of Cornah on the south is wholly occupied by the inland extension of the Lonan Flags. These hard flags, weathering more or less slaty in crags but showing little or no trace of fissility in the stream-courses, are well exposed in the picturesque little glen south of *Ballaglass* and on the hill-top beyond, at *Ballachrink*. In the glen an attempt has been made to develop a lead-mine (p. 342), and in the bed of the stream, 50 yards to the westward of the ruined mine-buildings, a curiously fresh-looking dyke, 2 feet wide, of lavender-grey close-grained splintery rock is exposed.

Following up the Cornah stream above the crossing of the main-road at Corran, we enter an area of the highly-contorted flaggy Agneash Grits which

are admirably displayed in all their intricate folding in the bold crags a little to the southward of the stream.

We are here in the proximity of the structural axis of the Island, since a little way farther to the south and south-east the prevalent dips are south-eastward, while in working westward upstream we find the limbs of the folds become more and more definitely inclined towards north-west, the cleavage-dips also swinging over, but not quite concurrently with the bedding. The mineral alteration of the slaty partings interbedded with the grits is very distinct in these sections, and continues westward throughout the glen. That its development is independent of the Dhoon granite seems indicated by its abatement in the rocks farther south and nearer to the granite.

Several of the north or N.N.W. to south or S.S.E. fractures which occur at intervals in the Cornah Glen have been systematically explored for metal-ores, but only one of the mines was in work at the time of the Survey (see pp. 524-5). One of these veins, which is exposed in the little side-ravine striking north to Park Lewellyn, has brought about extensive decomposition of the country-rock in its vicinity, the striped slates being softened and stained into rich lilac, green, and purple-red shaly clay, and the grit bands and quartz-veins reduced to a sharp quartz-sand.

The same peculiarities are visible at the head of a parallel and immediately opposite gully on the other side of the main stream; and again in the upper reaches of the valley, on the slope below Clagh Ouyre, where the decomposed slate seems to follow the general strike of the strata, as it also does in Dhoon Bay and Bulgham (p. 130).

The massive bands of quartzite which cross the stream opposite Cornah farm are probably the continuation of those of Margher-e-kew and Magher-e-breck. The manner in which these bands ascend the adjacent southern hill-slope has been described in the foregoing chapter (p. 40).

In two places in the stream-bed, between 150 and 300 yards to the east of the 'North Laxey' Mine, crushed strips of 'greenstone' are exposed, and a small dyke of the same kind is cut in an upper level of the mine. Higher up the valley, on the north bank of the river, 350 yards west of the mine, there is a larger boss of 'greenstone' among sheared and altered striped flaggy slates of the 'unseparated' type; and 300 yards still farther south-westward we find a weathered basic intrusion which may be traced thence at intervals for 200 to 300 yards, to the head of the glen. Climbing then to the grassy moorland-ridge separating the Cornah valley from Laxey Glen, we discover further indications of greenstone dykes in small rock-exposures along the old mountain-road going N.W. toward Snaefell, half a mile east of the summit of Slieau Lhean (1,515 feet), where we are once more within the belt of the Agneash Grits.

Turning eastward along this ridge (which lies wholly within 6-inch AGNEASH Sheet 8), we find at intervals obscure outcrops of dark banded slate with numerous flaggy layers of grit, while below us to the southward lies the typical exposure of highly-contorted quartz-veined grits in Creg Agneash. Where we cross the structural anticline in this vicinity the beds are folded almost vertically, but in Creg Agneash the grits on the whole show a north-westerly inclination, while the more slaty strata at lower levels along the same axis, in *Glion Ruy* (the upper portion of Glen Agneash¹), are turned

¹ It is a peculiarity of Manx topographical nomenclature that the name is applied to the glen and not to the stream, and that different portions of the same glen receive different names. The Agneash stream is a case in point: its total length is 1½ miles; it starts in Glion Ruy; flows through Glen Agneash; into Glen Mooar; and then joins the main stream in Laxey Glen. (See six-inch map, Sheet 8.) As another example, in Sheet 12 we have Glen Rushen continuing into Glen Mooar and Glen Meay. To the stay-at-home Manx crofter of old days the method might have its advantages, but it is confusing for anyone not wishing to spend his life in one glen, especially as almost every stream in the Island has its Glen Mooar (Big Glen) somewhere or other.

over to the opposite quarter, illustrating the point already commented on (p. 45), that in the neighbourhood of the anticline, where the dips are very steep the grits frequently hang over towards one direction and the slates towards the opposite.

From the manner in which the grits keep to the high ground around the head of *Glion Ruy*, leaving the intermediate hollow to the striped slates and flags of the 'Lonan Flags' type, it would appear that the valley descends below the horizon of the folded grit-platform. But the pioneer level driven northward from Dumbell Shaft of the Great Laxey Mine (two-thirds of a mile to the southward), at a depth of over 2,000 feet beneath the summit of Creg Agneash, encountered flaggy grits like those forming the Creg, apparently indicating that some portion of the grits are continuous downward to that depth. Several fault-like fractures are visible in the stream-bed of *Glion Ruy*, and as usual we are unable to decide whether faulting or folding should be held responsible for the position of the strata.

On the summit of *Slieau Ouyr* the quartz-veined grit-bands become less prominent, merging gradually into pale sandy Lonan flags like those of Port Cornah. We are here within 600 yards of the edge of the *Dhoon Granite* on *Slieau Ruy*, but the rocks do not show any notable increase in the degree of alteration.

Dhoon Granite.

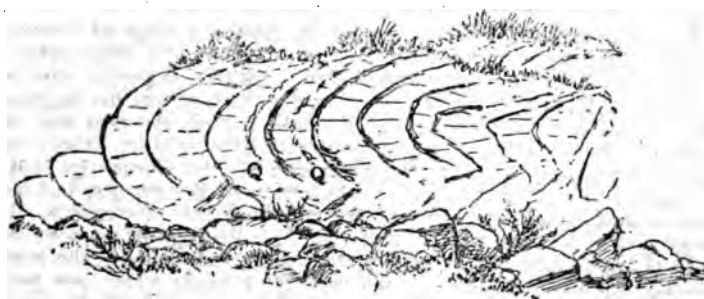
Though the ground is heather-covered, with only meagre exposures, the margin of the granite on the crest of *Slieau Ruy* can be fixed within a few yards. It is 630 yards S.E. of the cairn marking the highest point of *Slieau Ouyr*, and the granite is continuous thence south-eastward along the parish boundary between Maughold and Lonan for 400 yards, when we pass from it again to sheared flags decidedly more altered than those of the opposite border. The granite itself has undergone movement after consolidation, being rendered schistose in places in a direction parallel to the fissility of the flags, especially along its north-western margin; and it seems probable that the strata which were originally in immediate contact with it may have been afterwards displaced by overthrusting or normal faulting, and that the slight amount of alteration now visible at some parts of its boundary may be thus explained (see p. 106). Westward the granite disappears within 100 yards below the crest-line of the hill, the slopes descending into *Glen Agneash* being wholly of sedimentary rock; and the deep levels of the Laxey mine, 1,600 feet below the *Glen*, are altogether in the flags, with an elvan, seen also at the surface, as the only indication of the proximity of the igneous mass. Eastward the granite extends with an irregular outline, for $1\frac{1}{2}$ miles, to *Barony Hill*.

Following its northern margin in this direction we find no good exposures until we cross the straight mountain-fence running N.W. from *Rhenney* towards Cornah, about 800 yards west of the high road, where in a craggy hillock separated from *Slieau Ruy* by a boggy hollow, we see the actual junction of the granite with the flags. The highly altered country-rock is here streaked with little apophyses of the intrusive material and crushed into a schist, while the margin of the granite is rendered platy by crushing and appears to have been actually folded, as shown in the following figure (p. 143). On leaving this hill, the boundary is lost beneath the thin drift-covering of the shallow depression along which runs the high-road, but we recover it on the rise of *Barony Hill*, 300 yards east of the road, where low outcrops scattered among the heather enable us to fix the line within narrow limits, the junction-phenomena being, however, less clearly seen than where above described. The north-eastern corner of the intrusion just reaches the long fence enclosing the summit of *Barony Hill*, and seems there to send out the more northerly of the two elvans which, as already stated (p.p. 129-30), may be traced eastward down the precipitous slope to the sea.

Turning southward from the fence, we have good indications of a ragged junction of the granite and flags for 150 yards farther, when the second

elvan breaks away from the mass, following a parallel course to the first into the cliffs. Near this point the boundary begins to show a westerly trend, but enters cultivated land and is not seen again until we reach an old quarry overgrown with gorse, 500 yards to the south-westward, on the verge of *Dhoon Glen*, below the ruined farmstead of *Kioneheinin*. In this quarry, the sheared granite margin is full of highly altered included fragments of the flags. We descend from this point 200 or 300 feet almost precipitously into the deep glen cut nearly to sea-level, in which we find altered slaty flags only, and the various mining levels driven beneath the Glen (p. 528) were also wholly within the slate-series, proving, as in Laxey Glen, the absence of any notable expansion of the granite downwards to some depth beneath the surface. The steep valley-walls of the branching feeder which flows south-eastward into *Dhoon Glen* below *Kioneheinin* reveal crags of slate cut by a thin elvan from the granite (noticed by Henslow¹); but above the point where the stream forks, both the easterly and westerly

FIG. 38. *Granite crag under Ordnance station on shoulder of Slieau Ruy W.S.W of Ballelin, exhibiting curved structure (not like concentric weathering) probably due to movement. Height about 8 feet.*



Q. Small quartz-veins participating in the curved arrangement.

branches have trenched the massive granite. The intrusive rock is here traversed by veins containing much fibrous tourmaline, which was formerly excavated in these glens for use as a polishing powder (p. 556). The rock adjacent to the veins is in places so thoroughly decomposed that it is easily dug with a spade.

In endeavouring to trace the southern boundary round westward across the aforementioned drift-covered depression, we can fix the margin within narrow limits in the shallow cuttings in weathered rock on the new tram-line; and then find no further evidence until 300 yards west of the high road, where the little gully of the north fork of *Dhoon Glen*, which below this point is wholly in slate, shows a poor exposure of granite apparently brought against the slate by a north and south fault. Thence we pass across two cultivated fields and the boggy hollow on the edge of the moorland, to the slope of *Slieau Ruy*, without further indication for the exact position of the junction.

The whole area of granite thus enclosed is about half a square mile in extent. A large quarry for paving setts by the side of the high-road half a mile north of *Dhoon Glen Hotel* affords the most favourable opportunity for studying the central portion of the intrusion. In this quarry the joint-faces are frequently coated with molybdenite. The petrographical features

¹ Trans. Geol. Soc., vol. v., p. 491.

of the mass and its relation to the other igneous rocks of the Island are discussed in Chapter VIII. p. 312.

To the northward of the granite the little stream which runs down the eastern slope of Slieau Ruy reveals a continuous section of baked gritty flags, having a predominant dip south-eastward, or *towards* the intrusion; and this is the general direction of the bedding and cleavage planes all round the mass. In fact, the granite does not appear to have affected the arrangement of the rocks into which it was intruded, but merely to have punched out room for itself through the previously packed and folded flags, and to have been affected after consolidation by a renewal of the shearing forces acting in the same direction as before, but with less intensity. It is highly suggestive that the only elvans which can be traced for any distance from the granite are those which stream out from opposite ends of the mass roughly parallel to the cleavage. Those from its eastern margin have already been described; and those from its extreme western margin take a similar course in the opposite direction, crossing Glen Agneash, Laxey Glen and Glen Roy, as indicated in Fig. 29, p. 84. Directly to the southward of the outcrop, with the exception of short protuberances close to the edge of the intrusion no dykes have been discovered; and to the northward, only one small elvan is found in the bed of the aforesaid stream from Slieau Ruy, 400 yards west of the upper high-road, and another on the northern slope of Barony Hill, 800 yards N.E. of Ballig, neither of which seems to extend more than a short distance from the granite. The dykes from the Foxdale granite present analogous features (see p. 311).

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If we follow the little stream round the northern slope of Barony Hill into the picturesque glen at Rhenab, three-quarters of a mile north of the granite, we find pale flaggy altered slate, with its dominant dips at first towards S.S.E., but afterwards changing, 600 yards east of the high-road, to the unusual direction of E. or E.N.E., with flattish cleavage and curious schistose structures almost or quite obliterating the bedding. This abnormal dip, corresponding to that on the north side of Port Cornah (p. 129), does not appear to be connected with the intrusion of the granite, but to have been caused by the proximity of the anticlinal axis of cleavage. In the lower part of its course the stream runs in a deep gully between vertical walls of highly confused baked splintery flags, still showing the abnormal easterly dip and traversed by schistose hard bands which are probably crushed greenstone dykes. There is something so peculiar in the structure and composition of these rocks that they deserved fuller investigation than they received, but the sections in the walls of the ravine are unfortunately difficult of access. Shreds of altered basic intrusions are visible on the slopes above the ravine on both sides,—to the northward in the steep road leading across to Cornah, and to the southward in the fields of the old Barony enclosure E. 15 N. of the shepherd's house.

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In the lower part of Laxey Glen (in Sheet 11) a narrow alluvial flat occupies the bottom of the valley, but the Lonan Flags with dominant S.E. dips are revealed in many sections in the steep slopes on both sides, occasionally traversed by small 'greenstone' dykes. The extensive mining work on the Great Laxey Lode, which has been one of the most productive metalliferous lodes in the British Islands, is described in Chap. XIII., p. 519.

The lode is a definite fracture-line striking about N. by W. and hading towards E., but it does not appear to be accompanied by faulting of much moment; its course leaves the main glen and enters that of the Agneash tributary (*Glen Moar*, 6-inch Sheet 8) above the junction of the streams, where for a few hundred yards it nearly coincides with the river-bed. The Bulgham Bay group of greenstone dykes (p. 131) seems to cross the same ravine, basic intrusions being obscurely exposed at short intervals wherever the country-rock is laid bare. Among these dykes there is, however, one—a mica-trap, seen in the stream-bed north of the Big Wheel—which has not been recognised in the coast-section. Farther upstream in Glen Agneash, above the mines, 200 yards north of the upper reservoir, the dyke of Dhoon microgranite, 20 feet wide, of which mention has already been made, is well exposed. It is also indistinctly seen in the moorland road to

E.N.E., 400 yards nearer the granite; and its *débris* is abundant in the spoil-heap of a small shaft on the opposite hill-side, 300 yards W.S.W. of the stream. A second dyke of similar composition, but only about $1\frac{1}{2}$ feet in width, is visible in Glen Agneash 450 yards north of the above-mentioned example. Pale hard sandy flags prevail in this part of the glen, intermediate in character between the Lonan Flags and the Agneash Grits; the bedding of these rocks is almost vertical, or turned over slightly toward S.S.E.

Returning to the main Laxeý Glen above its junction with Glen Agneash, we find similar sandy flags revealed at intervals in the valley bottom, highly crumpled and folded, but with a tendency toward W.N.W. Among these flags, bands of quartz-veined grit make their appearance, and increase in numbers in going westward, until the rocks attain the typical characters of the Agneash Grits. The thin slaty partings among these grits are sometimes full of partially-developed alteration-minerals of much petrographical interest (see p. 109).

A fine 20-feet dyke of microgranite like that of Agneash is exposed in the Laxeý stream rather over three-quarters of a mile above the aforesaid junction, or 950 yards S.E. of the farm of Laggan Agneash. Its position is somewhat to the eastward of the line of strike of the Agneash dyke, but there is little doubt that they are identical. The manner in which these intrusions have been chopped up into segments that have been displaced either by faulting or folding, is evident in the crags of the high valley slopes on either side. On the north we find a sheared and broken elvan of the Dhoon type among the grits bordering the rivulet which tumbles into the Glen 150 yards east of Laggan Agneash; but in the stream-bed and on the opposite or southern side of the valley, we search in vain for its direct prolongation, until we go 500 or 600 yards farther east on the south side of the valley, where, in the tramway cutting and the crags above and below it, we encounter an excellent exposure of a similar elvan, about 15 feet wide, accompanied by others of smaller dimensions. There is much reason to believe that, in spite of their apparent discontinuity, the above described outcrop in the river and those of the north and south slopes of the valley have once been continuous and all represent parts of the same elvan. Two hundred yards farther south there is another exposure of microgranite, on the hillside below the tramline; and yet another, 500 yards distant from the large dyke in the tramway cutting, in the gully of a rivulet flowing eastward into the main glen. These also are discontinuous along their strike (see p. 314).

In the higher reaches of Laxeý Glen we pass out of the Agneash Grits into banded slates of the 'unseparated' type. These lie within the belt of alteration, and present the usual indications of incipient metamorphism. In the vicinity of Laggan Agneash several small dykes of altered greenstone and one or two of the intermediate type are revealed in the stream-bed, and others again 200 to 400 yards farther westward. Where the stream forks, just below the Snaefell Leadmine (p. 526), the strata are greatly shattered, and it is probable that a fault of some magnitude crosses the valley at this point, striking N.N.W. along the course of the north fork. This crushed slate is seen in the banks of the stream and also proved in the underground workings of the mine; the slates are similarly shattered on a prolongation of the same line in the tramway cuttings on the southern side of Laxeý Glen. This disturbance may be responsible for the truncation of the northern edge of the Agneash Grits on the lower slope of the hill above the Snaefell mine; though, as usual, an alternative explanation can be offered, in the supposition that the valley-bottom at this point may descend below the level of the sheet of grits.

A small dyke of actinolitic greenstone occurs in the bed of the north fork about 20 yards above the shaft of the mine, and another larger dyke-like band crosses the stream 300 yards farther north. In the south fork, above which the tramline runs, strongly banded sandy flags with thin gritty layers are found, exhibiting excellent instances of partial brecciation. The tramline itself between this point and Laxeý presents a fine succession of sections in which the complex folding and buckling of the Agneash Grits

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may be advantageously studied. Several basic dykes and elvans, like those in the river bed, are also laid bare, but are generally much weathered.

There is a small quarry by the side of the mountain-path, 500 yards E.S.E. of the hotel at the crossing of the tramway and the high-road on the southern shoulder of Snaefell, in which the alteration of the banded slates is almost as well displayed as in the cuttings on the western slope of Snaefell (p. 110). The rock is streaked and frilled by intersecting planes of strain-slip; and small garnets and other minerals are abundantly developed in certain layers of argillaceous material adjacent to little beds of harder grit. Continuing along the aforesaid path, the high ridge of Mullagh Ouyr (in Sheet 7), chiefly composed of the quartz-veined Agneash Grits, lies to the south of us, while to the north we find a tract of altered 'unseparated' slaty rocks which are perhaps brought in by the effect of the Snaefell Mine fault, and occupy the moorland for about half a mile farther eastward, until replaced, in Cronk y Vaare (in Sheet 8) and the upland to the south-eastward, by the Grits. The heads of the little streams draining southward from these uplands will be described when we reach the drainage system of which they form part (see p. 160).

CENTRAL DIVISION (*Six-inch Sheets 9 to 14*).

Western Coast.

The description of the western coast-line of this division northward of Peel is given in the chapter on the Peel Sandstones (Chap. VI., p. 272). In Peel Bay the fault which forms the western boundary of these Sandstones is concealed by drift, which descends in this vicinity considerably below sea-level (see pp. 441-3). On the western horn of the Bay, however, the Slate Series reappears, and is continuous thence southward to the extremity of the Island. For the first six miles (including the remainder of Sheet 9 and the northern third of Sheet 12) the coast-sections consist exclusively (save for a capping of drift) of the Niarbyl Flags.

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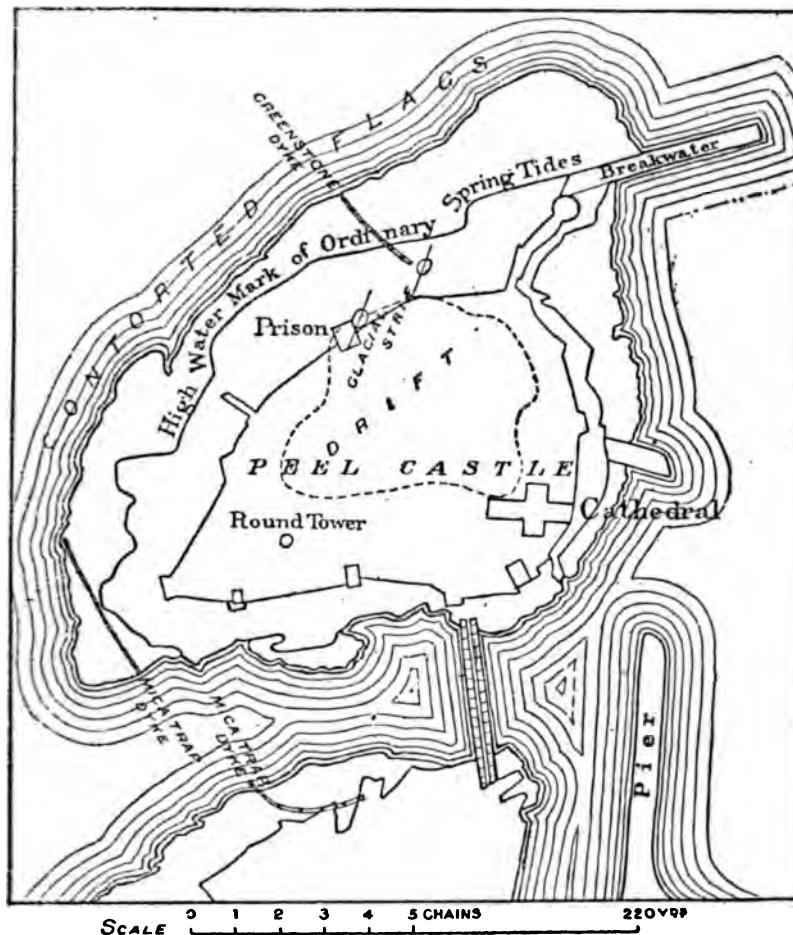
The most easily accessible locality on the coast for the study of these rocks is St. Patrick's Isle, close to Peel. The shore here is low and shelving; and though very rugged, as indeed it always is when composed of the slate-rocks, it can be traversed without difficulty by the pathway under the outer walls of the Castle-yard. The palish grey and blue slaty flags here seen present a succession of folds, in some places rather open and in others pinched up so that the limbs are highly inclined; and in the troughs of the folds the pseudo-ripple-marking is sometimes well developed. There is a faint cleavage, of low angle, crossing the bedding; and the flags are fractured in places by fault-like lines of crushing. As indicated on the following enlarged plan of the Isle, two dykes, with possibly the crushed remnant of a third which is not shown, traverse the strata in a N.N.W. direction. The more easterly is one of the less crushed 'greenstones'; the more westerly, a fine example of mica-trap with conspicuous crystals of mica in a micaceous ground-mass. The latter dyke gives rise to a long channel near high-water-mark at the south-western angle of the Isle, and affords by far the best Manx exposure of this type of intrusion, elsewhere either scantily visible or outcropping in almost inaccessible positions. The same dyke is prolonged into the mainland cliff on the opposite side of the water-gully.

TTRARY
AD

Most of the shore between St. Patrick's Isle and Contrary Head is only approachable by boat, though a risky descent of the cliffs may be made in one or two of the little bays. In every section the Niarbyl Flags exhibit magnificent contortions, the limbs of the folds usually standing at high angles and the troughs exhibiting much pseudo-ripple-marking and other interesting pressure-structures (see Figs. 21-3, pp. 77-9). Occasionally the folds show domed or boat-shaped terminations, but unlike the plications of the eastern coast, these do not show a steady pitch towards one quarter. The cleavage varies considerably both in intensity and in angle of dip, being influenced in the latter particular in part by the wide differences in

the texture of the individual beds, and in part probably by post-cleavage disturbances. In the more slaty bands between Peel and Contrary Head it is occasionally sufficiently strong to have encouraged small slate-trials;

FIG. 39.—*Plan of St. Patrick's Isle, Peel, showing position of dykes traversing contorted Niarbyl Flags.*



and in certain limited beds the quality of the product seems to have been better than is usual in the Island, but the quantity obtainable was too small for profitable working.

Fractures and lines of crushing abound, striking both along and across the direction of stratification. Small thrust-planes of low hade are also common, especially between Dalby Point and the Niarbyl.

Dykes are not numerous, and are all of small size. Instead of following the bedding planes like the majority of the dykes of the opposite coast, they have usually a N.N.W. strike, or nearly at right angles to the bedding. They

have all been injected after the folding, and are as a rule fresher and less crushed than is commonly the case with the Pre-Carboniferous intrusions of the Island; but that they are Pre-Carboniferous is indicated by the fact that while they traverse the slates all round the margin of Peel Sandstone, not one has been found to enter that formation. Several of these intrusions belong to the mica-trap group, this type being better represented here than in any other part of the Island. As the dykes in this area are widely spaced, it has been possible to show most of them on the one-inch map; and their position will, therefore, scarcely need further indication. On the north side of Contrary Head, near the base of the cliff, two little seams, 4 inches thick, of a curious pale-yellowish-green steatitic material may be seen, apparently interbedded with the flags. These are possibly of igneous origin but are too much altered to reveal their genesis even to microscopic examination. Similar but still thinner seams were observed on the coast farther south in the vicinity of Dalby, and again on the eastern coast between Douglas Harbour and Douglas Head. They deserve mention because of a somewhat remote possibility that they may represent altered volcanic material.

Besides the outcrops in the cliff, one of the mica-trap dykes is exposed in two places in the crags, 300 to 400 yards inland from the coast south of Contrary Head, and 800 yards S.S.W. of Knockaloe Moar farmstead. On the same craggy ridge half a mile farther east, in a quarry in the Niarbyl Flags 50 yards west of the high road to Dalby, another basic dyke 6 feet wide is rather well seen. These are the only inland instances within the boundaries of the Niarbyl Flag where dykes have been observed, except in a doubtful case in Glen Meay close to the eastern edge of the division.

COAST
SOUTH OF
CONTRARY
HEAD.

The cliffs to the southward of Contrary Head resemble those already described. At Glen Meay the coast is broken by a little precipitous east-to-west ravine carved out of the Flags, which coincides in part with a line of faulting, the fault breccia being revealed in places in its southern wall.¹ To the southward of this place the cliffs are lower and the foreshore broader, rendering the sections more easily accessible. A typical section on this part of the coast has been illustrated in a previous figure (see Fig. 3 p. 37).

A dyke of 'greenstone,' 6 feet wide, traverses the foreshore opposite Ballaquane 850 yards south of Glen Meay. In the next recess southward, where the cart-road from Ballaquane reaches the shore, three small intrusions of olivine-dolerite are visible, the largest 3 feet wide, striking N.W. or N.N.W. This is the most northerly instance of the supposed Tertiary intrusives that we have observed on the western coast. Another dyke of like character and dimensions occurs on the north side of Dalby Point, half a mile S.W. of the last; and a third at *Baig ny Ooig*, 130 yards beyond, on the southern side of the Point; and no further example is then known for more than two miles, after which the coast intercepts another small cluster of these dykes (pp. 150-1).

The finer-grained flaggy beds in these sections usually all contain a trace of lime, but that substance is most abundant in certain bands between Dalby Point and Glen Meay, referred to on p. 36. At Elby Point close to The Niarbyl, the bedding planes exhibit the beautiful reticulate structures illustrated in Figs. 21-2, pp. 77-8.

THE
NIARBYL.

The Niarbyl is a rough low reef of folded flags, one-third of a mile in length, at high water cut up into islands and partly submerged; and in this reef the Niarbyl Flags suddenly terminate, as already described (p. 35). The existence of the reef is due to the superior endurance of these flags over the softer strata to the southward, which consist of striped slates and thin sandy bands of the 'unseparated' type, greatly crushed and disturbed. At low water, when the edge of the reef is exposed, the softer beds seem to pass under the flags at an angle of about 25 degrees, an irregular streak of

¹This breccia seems to have been regarded by Harkness and Nicholson as a true conglomerate (see p. 163). See Quart. Journ. Geol. Soc., vol. xxii, p. 489.

crushed rock and vein-stuff occupying the junction. In the adjacent little cliff, however, the line of division is steeper and more like a normal fault. The present relationship of the rocks at the junction is clearly due to some form of displacement; and if we are right in considering the flags to be the older division, we must, as already stated (p. 38), grant the existence of an overthrust at this point.

A small 'greenstone' dyke, 1 to 2 feet wide, strikes north-westward across the reef, 150 yards S.W. of the fisherman's house on the little beach. Among the softer beds in the floor of the bay, some curious disconnected bosses apparently of igneous origin are visible at low water, probably the remnants of a shattered intrusion of altered diorite (p. 300). From this place southward, small dykes of 'sheared greenstone' of the older type, often reduced to the condition of calc-chlorite-schist, are numerous; and these usually strike with the cleavage, or E.N.E. to W.S.W. The remarkable difference in the number, character and direction of the dykes in these slaty rocks as compared with those in the Niarbyl Flags seems at first sight to suggest that the Flags belong to a later system than the Slates, and that some of the dykes which traverse the Slates may have been intruded before the Flags were deposited. But such a reading would mean a reversal of the order of succession advocated in the preceding chapter, and would imply a time-interval if not an actual unconformity between the divisions for which there is no other evidence. The suggestion is mentioned merely to show that it has been duly considered, and rejected in favour of the more probable explanation that the phenomena in question are due in the first place to the less penetrable character of the Flags, and secondly to their superior resistance as a mass to the later shearing-stresses, so that to a considerable extent, they protected and preserved the comparatively few intrusions that found entrance into them (see p. 299).

An outstanding stack in *Traie Vrish*, 360 yards south of the Niarbyl COAST Cottage, is penetrated by one of the greenstone dykes. This appears to have SOUTH been folded and broken by small overthrusts, affording a good illustration OF THE of the deformation which the intrusions have suffered among the softer NIARBYL rocks in this quarter.

In the same locality, an adit has recently been driven into the cliff to explore a lode which many years ago yielded a small quantity of sulphide of antimony (p. 546). The dark striped slates on the foreshore contain many small nodules, as well as worm-like impressions. On the southern side of *Traie Vane*, where the *Lag River* pours in a little cascade to the shore, a belt of beautifully banded pale and dark green slates is revealed (see p. 123). The same slates are doubtfully recognisable in a few places on the steep hill-slopes east of Dalby, their appearance in weathered inland exposures being, however, not nearly so striking as on the smooth rock-surfaces of the sea-shore. Lustrous sericitic slates occupy the shore and the cliffs farther southward, while, as shown on the one-inch map, a darker belt, probably representing an infold of the Barrule Slates, is exposed in the high broken precipices of *Fheustal*, three-quarters of a mile south of The Niarbyl. The same cliff is traversed by a band of tough ferruginous rock, in places 30 feet wide, which is probably a decomposed basic dyke; and several other similar 'hard bands' of indefinite character occur between this place and Gob yn Ushtey. In approaching the latter locality we find the rocks assuming a more arenaceous aspect, with gritty layers which are frequently broken into pebble-like fragments, forming thin streaks of 'crush conglomerate,' as may be well seen on the southern side of *Gob Breac* (six-inch map, Sheet 12). Under Gob yn Ushtey we encounter bands of rather coarse grit, in the vicinity of which the slaty material has become schist-like, through shearing. Among the numerous dykes in this neighbourhood is one which has a width of 20 feet. It adjoins the coarse grit, near the cascade formed by the stream from Glion Moor. Vein-quartz abounds in these sections; and some of the fractures which gash the cliff may indicate faults of consequence, but the stratigraphy is too confused to enable us to estimate their value. In the face of the cliff 100 yards north

of Gob yn Ushtey, where there is a local coincidence of bedding and cleavage, an attempt has been made to win roofing slate.

South of Gob yn Ushtey the upper portion of the high precipices are, for 300 or 400 yards, largely composed of flaggy grits, as shown on the map; but these do not always descend to the shore, which is still chiefly occupied by dark striped slates with occasional grit-bands. It would require a long and exceedingly difficult and even dangerous investigation to unravel the complexities of these coast-sections. For long stretches of the western coast south of the The Niarbyl it is only possible to approach the base of the great precipices by boat on the rare days of absolute calm; and in the few places where a precarious descent from above is practicable, the roughness of the block-strewn shore and the recurrence, at short intervals, of deep water channels which the sea has scooped out along the crushed fracture-lines, makes any progress arduous and risky. Under such conditions the work would be difficult even if the geology were simple; while, as the matter stands, this coast truncates the central axis of the Island and exhibits every form of complicated structure possessed by the much troubled massif.

Of the numerous dykes in the next half-mile south Gob yn Ushtey, some belong to the dark less altered greenstone group, but more to the highly sheared calc-chlorite-schists of the most hopeless type. Among the latter is the dyke, 20 feet wide, at *Da Leura* (of the six-inch map; the name should probably be written *Dal Eura* or *Eairy*), of which a description and analysis by Mr. Teall is given at p. 308. Another broad dyke-like mass, probably igneous though at first thought to be a pale mudstone, occupies the cliff at *Ooig ny Sevir*, 200 yards north of *Lag ny Keeilley* where *Chapel* is engraved on the one-inch map.

At *Con Shellagh*, 500 yards north of *Lag ny Keeilley*, a beautiful little fern-draped cave, into which the sea does not now penetrate, appears to belong to the Raised-beach period, and affords evidence of the slow rate of recession of this coast. The cave is well adapted for a hiding-place, and might repay archaeological investigation.

NY
ILLEY.

In the circle of crags surrounding *Lag ny Keeilley*, and also on the moorland slope above, 50 to 80 yards N.W. of the boundary between the parishes of Patrick and Arbory, we encounter the most northerly examples on the west coast of the microgranite elvans of the Foxdale type. These are fine-grained pale felsitic dyke-rocks, usually highly sheared, which might readily be mistaken for fine grits. They are, however, characterised by the presence of small hexagonal crystals of white-mica, sparsely distributed through the crypto-crystalline ground-mass. Further petrographical details respecting them are given at p. 316. Like the Dhoon elvans of the opposite coast, these dykes are broken in the moorland exposures into disconnected shreds, which apparently do not descend directly to the coast, but are distributed *en échelon* on the crest of the southern spur of Cronk ny Arrey Lhaa, separate segments being found in the crags *Burrow Sodjey*, *Burrow Meanagh*, and *Burrow Mooar*, whence they at last descend to the coast, over half a mile south of their first appearance on the brow above.

From *Lag ny Keeilley* southward to Stroin Vuigh the cliff is composed of the welded dark blue Barrule Slates, which descend in a crumpled mass, full of quartz veins, in ranges of precipices, from the summit of Cronk ny Arrey Lhaa (1,449 feet) to the sea. Three hundred yards north of Stroin Vuigh one of the Tertiary (?) olivine-dolerite dykes, 3 feet wide, striking W. 15 N., emerges in the cliff. Immediately to the southward of Stroin there is a curious plexus of dykes of all ages; along with several small examples of the sheared calc-chlorite-schist type, we find here a less sheared greenstone, accompanied and apparently cut by a small Foxdale elvan, and the two intersected by an olivine-dolerite 6 feet wide. A little farther southward, under *Ny Pheastul*, a twisted and disjointed elvan about 10 feet wide wriggles along the cliff-face for 50 or 60 yards. Tough fibrous slate has been quarried close by.

SLOCK.

At *Y Slogh* (known now as The Slock), adjoining "The Stacks" of the one-inch map, the principal batch of elvans, after hugging the brow of

the precipice as already described, comes down to the shore in a complicated group of segments, again accompanied by small sheared greenstones. The elvans seem to be displaced again by an east and west fracture, along which, in the cliff, a mining level has been driven in search of lead ore (see page 536). The country-rock in this vicinity is a pale somewhat sandy flaggy slate, not unlike the more argillaceous portion of the Lonan Flags.

In the cliff 300 yards farther south there is another exposure of a large elvan, 30 or 40 feet wide. This elvan is distinctly traversed by a small flier of olivine-dolerite about one foot wide, probably an offshoot from a broader dyke of the same material which may be hidden by talus in an adjacent gaw.

Having now reached the southern edge of the Central Division (Sheet 12) on this coast, we will turn to the examination of the eastern coast in the division. The description of the remaining portion of the western coast of the Island is resumed at p. 171.

Eastern Coast of the Central Division.

(Six-Inch Sheets 11, 14, and 13.)

Commencing at the northern edge of Sheet 11 of the six-inch map, on the eastern coast about a mile to the northward of Laxey Head, we find LAXEY that for some distance the shore-line nearly coincides with the strike of the HEAD. rocks, and as the beds are inclined steeply south-east, or seaward, the cliff presents the typical dip-slope characters. The rocks consist of Lonan Flags, of the usual type and with the usual structure, which extend from this place southward to Clay Head with only minor changes. Toward Laxey Head some of the bands are peculiar in containing cubical crystals of pyrites, while nodules and 'worm-tracks' are common in many places. Several small dykes of greenstone occur; and one of these, best seen in the neighbourhood of Skeirrip, is veined with quartz after the manner of the Agneash Grits. Two of these dykes are visible in the low cliff on the north side of Laxey Harbour. The notch in the crest of the cliff due east of Skinscoe farmstead marks an old channel of the little *Strooan ny Gragee* which now pours over the cliff through a new gully 200 yards farther south.

On the southern side of Laxey the rocks on the shore at high water contain the hollows left by decomposed nodules, which have given rise to so much discussion under the supposition that they might be "footprints" (see pp. 20, 90). From the aspect of the shore opposite the village, it is probable that boulder-clay underlies the beach-material in a pre-glacial prolongation of Laxey Glen, but no exposure was detected during the Survey.

Dykes of greenstone occur in increasing numbers southward, being especially plentiful about three-quarters of a mile south of Laxey. Their direction is more to the northward than usual, being approximately N.E. A fine dyke of olivine-dolerite, 6 feet wide, is visible on the shore 800 yards north of Garwick. Its north wall, well exposed in the cliff, shows a close-set system of parallel joints; its course is somewhat abnormal, being a little S. of W., but the dyke seems to have been slightly displaced by a neighbouring small fault. Usually when one of these dykes is found, others are not far distant; but this instance, so far as is known, is solitary, its nearest companion being one and three-quarter miles to the southward.

In Garwick Bay and on Clay Head fault-like fractures roughly parallel to the strike of the flags are very numerous, and some of them have been tested for metalliferous ores by short adits. The general inclination of the contorted bedding continues to be south-eastward until we pass *Braggan Point* (six-inch Sheet 11), when it swings round by south and west (indicating the westerly pitch of the folds) and attains a steep north-westerly direction, which thence predominates on Clay Head and the coast southward, as far as Onchan Harbour. The axis of the synclinal trough runs roughly parallel to the coast and is never more than a few hundred yards

GARWICK
BAY.

inland (see Fig. 29, p. 84). The S.S.E. cleavage is not affected by the reversal of bedding, and therefore in this part of the Island, unlike the usual conditions, is more or less directly transverse to the bedding planes. It is noteworthy that here, as on Laxey Head, the minor plications of the limbs of the folds are often so arranged that their axial planes are parallel to the cleavage, as described and figured in the previous chapter (Fig. 30, p. 85). The narrow belt of thick-bedded quartz-veined grits, described on p. 46, which appears to be a local modification of the Lonan Flags, is intercepted by the cliff-line on the south side of Garwick Bay, 200 to 300 yards S.E. of the mouth of *Glen Gavone*.

Among the dykes of this part of the coast, the following are the more noteworthy. In Garwick Bay a porphyritic greenstone, 10 feet wide, strikes N.N.E. across the beach on the south side of the Glen. Between *Gob ny Stowell* and *Braggan Point*, 600 yards farther to S.E., a curious boss of diorite, sheared around the edges, is exposed on the foreshore (see p. 300). It contains pinkish patches of more acid composition, recalling in this respect the mica-trap of Groudle (p. 302). A small dyke goes out from it which cannot be distinguished from the usual type of 'greenstone.' At The Clytt on the S. side of Clay Head, a dyke of unusual character, about 4 feet wide, strikes S.W. across the little promontory, and thence across the shore for 200 yards (see p. 328). It contains large porphyritic feldspars and is uncrushed, though slightly displaced 150 yards S. of The Clytt by a small N.—S. fault. Its joints, like those of the adjacent country-rock, are in places stained with hematite. It hades with the S.E. cleavage and not with the N.W. bedding. It is evidently newer than the ordinary 'greenstones,' but may be older than the olivine-dolerites; there seems to be no other dyke in the Island with which it can be directly compared. An olivine-dolerite, 4 feet thick, striking N.W., is seen in the cliff 450 yards S. of The Clytt, and must intercept the above-described intrusion at about 200 yards inland. Several broken dykes of rough slightly-sheared quartz-veined greenstone occur in the cliffs farther south; the smaller strike N.E. with the flags; but two of the larger, each about 12 feet wide, 1 mile S. of Clay Head, have apparently a transverse direction.

In this quarter the westerly pitch of the troughs and crests of the folded flags is well seen at the base of the cliff.

Entering upon Sheet 14 (six-inch), we find a plexus of greenstones in *Baih Doo*, half a mile east of Port Groudle, and some smaller examples 300 yards farther west, the latter having an interrupted course S.W., to the north side of Groudle. It is perhaps the same group which reappears on the opposite shore of the Port, 60 to 100 yards S. of the shingle beach.

Besides the usual crush-lines and cross-fractures, the sandy flags of this locality are traversed by joint-like planes, inclined at about 30° towards S. 25 E., thinly coated with striated vein-quartz. These are independent of both cleavage and bedding.

On the shore of the westerly shoulder of Port Groudle, 250 yards south of the storm-beach, a mass of hornblendic mica-trap, about 50 feet wide, is exposed (see p. 302 for petrographical description). It is a dark micaceous rock, somewhat vesicular at the margin, permeated with veins and patches of pinkish material more acid than the mass. It strikes N.W. along the N.E. slopes of Banks Howe, being visible in two small outcrops in the park below the electric tramway and again on the upper side of the line. A better exposure occurs higher up the hill, 250 yards (as measured on the 6-inch map) south of the Groudle Tram-Station, where its strike appears to be nearly E.—W. At this place it could be conveniently quarried, and would probably, from its toughness, furnish useful road metal. It seems to occur, like most of the older Manx dykes, not continuously but as a series of lenticular bosses. No trace of it has been found in Groudle Glen.

A smaller dyke of quite different character, apparently one of the less altered greenstones, is also exposed for a short space on Banks Howe, 60 or 70 yards west of the most westerly outcrop of the mica-diorite.

West of the mica-diorite the coast for some distance runs parallel to the **NORTHER** strike of the rocks. The flags dip into the cliff, and their edges protrude **SIDE OF** with a jagged ladder-like outline very different from the dip-slopes north of **DOUGLAS** Laxey. Shreds of narrow 'greenstone' intrusions occur here and there, **BAY.** striking with the flags, but hading with the cleavage and across the bedding.

In Onchan Harbour, where the coast recedes into the trough of the syncline, the beds are folded almost vertically. The N.N.W. fractures which have given rise to this recess seem somewhat to shift the axis of the trough, and may therefore mark faults of some moment. The basic dykes are again abundant in this neighbourhood, the largest, 12 feet thick, crossing the strike of the flags on the western side of the Harbour. Several smaller intrusions, striking with the country-rock, cross the little headland into *Port Jack*, being well shown in the tramway cutting under Douglas Bay Hotel. The westerly trend of the coast having now carried us to the westward side of the syncline, we find on rounding the headland into Douglas Bay that the general dip of the flags is again south-easterly.

In *Port Jack*, a little to the westward of the trough, a belt of quartz-veined grits like that of the north side of Clay Head is encountered, and it appears probable that, as shown on the map, a more or less continuous inland strip may connect the two localities (see p. 161), though if so, it lies nearer the axis of the syncline at Port Jack than at Clay Head.

The low-water rocks on the broad foreshore of Douglas Bay (6-inch Sheet 13) are for the most part greatly obscured by seaweed. They consist of Lonan Flags, rather slaty in places but with occasional gritty bands, much folded, with a general dip at high angles south-eastward up to the centre of the Bay and then north-westward, the synclinal trough crossing the shore again in the southern part of the Bay, between Conister Rock and the mainland. The pitch of the folds, where it can be observed, is south-westward. It is probable that a thin covering of drift may rest on the solid rocks in some parts of the inner curve of the Bay, where the beach is covered with sand and shingle, as the slope in the southern part of the town is drift-covered to its base. There is a curious gap in the low-water scars opposite *Broadway*, which may mark a preglacial channel (see p. 446).

At the northern extremity of the Bay a 'greenstone' dyke, 10 feet or more in width, traverses the foreshore to the eastward of *Derby Castle*; and what is probably another segment of the same strikes into the cliff behind the Electric Power Station. A smaller dyke of similar character is seen in the stone-quarries behind the houses at the bottom of *Burntmill Hill*; another, or the same, is visible near the mouth of the little ravine of *Glen Crutchery*; while other thin segments occur in the rock-face behind *Mona Cliff House* (of 6-inch map); in the grounds of *Falcon Cliff*; and in a few places on the shores of the Bay in this vicinity. A porphyritic basic dyke, 2 or 3 feet wide, which strikes north-westward across the shore 300 yards west of Derby Castle, appears to be of the 'newer greenstone' type, but its relations are ill-defined.

Near this place the discovery of pieces of graphite on the shore has led to the driving of an adit northward into the cliff 200 yards west of Derby Castle, and it is said that a lode has been encountered which carries a small quantity of gold (see p. 548).

On the southern side of the Bay the insulated Conister Rock furnishes good examples of the smaller greenstone intrusions, and shows the manner in which they are cut and displaced by minor faults. Similar dykes are seen both outside and inside the harbour in the rocks on which the New Pier is built; and again, on the opposite side of the Harbour, in the quarry on the hillside due south of the new Swing-Bridge. The extensive quarries which break the lower slopes of the hill in this quarter have supplied most of the building stone for Douglas. They are in slaty flags with some gritty bands, dipping W.N.W. at angles usually between 65° and 80°. Higher up the hill are the ruins of an abortive mining trial for lead (p. 544.)

SOUTHER
SIDE OF
DOUGLAS
BAY.

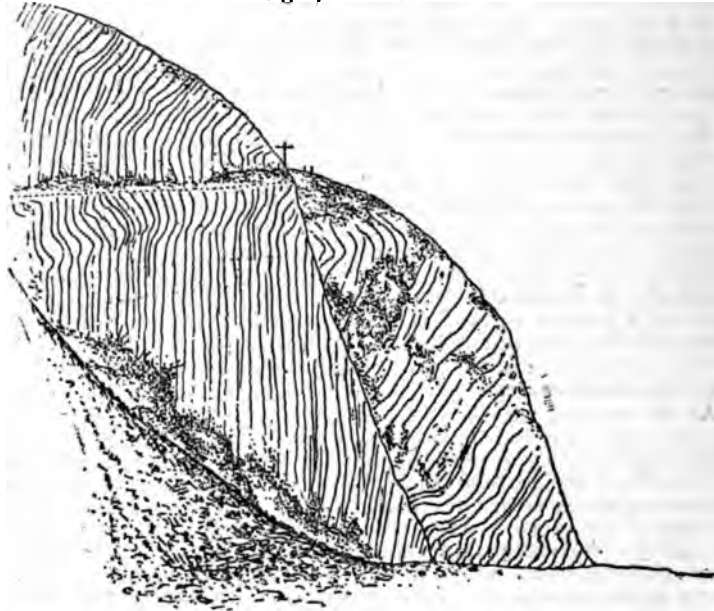
GLAS
D.

On Douglas Head outside the harbour, a 6-ft. 'greenstone' is visible on the foreshore 30 yards east of the outer Pier. Close by, and possibly associated with it, there is a curious pale seam, an inch thick, among the Flags, like those noticed at Contrary Head and Dalby Point (p. 148).

Under the lighthouse the trough of a fold pitching N.E. is well exposed. It is interrupted by a line of fracture and crushing which can be traced in the face of the cliff south-westward for 700 or 800 yards. There are two broken greenstone dykes at the base of the section 80 to 110 yards S. of the

FIG. 40. *Diagram of cliff at The Whing, north-east of Port Soderick, showing varying inclination of bedding-planes of gritty flags between summit and base of section.*

Height, about 300 feet



NOTE.—The tramway cutting is indicated in the upper part of the cliff.

Lighthouse; another below high-water mark at *Fiddler's Green* (6-inch map Sheet 13) 500 yards farther S.W.; two in the tramway cutting on the crest of the cliff between this point and *Pigeon Stream*; another in the rock-walls on both sides of *Slack Indigo*; and others on the coast and in the tramway cuttings farther westward.

An intrusion, 5 feet wide, of different type, occurs 200 yards W. of *Slack Indigo* (five-sixths of a mile from Douglas Head Lighthouse). It strikes N.W. up the face of the cliff, and is again revealed, in the condition of weathered ferruginous spheroids, in the tramway cutting above. Its field-characters suggest that it might be classed with the olivine-dolerite group, but its petrographical examination has thrown doubt on this correlation (see p. 329). In the cliff-section, a segment of this dyke, 8 feet in length, is displaced 10 feet to the northward between two small parallel slides.

At *Port Walberry* there are indications of a north and south fault of some importance, with a downthrow eastward. On the westward side, dykes make their appearance in increased numbers. One of these, 10 to 15 feet wide, is more or less continuous for about 200 yards, between *Horse Leap* and *Purt ny Coan*, and an intrusion of similar aspect is seen at low water in the outer rocks of Little Ness. Some of the dykes on Little Ness seem to belong to the 'newer greenstone' group; but it must be acknowledged that while the differences between extreme examples of the older and the newer set are strongly marked, there are many individual dykes of intermediate character which one hesitates whether to assign to the one set or to the other.

On the extremity of Little Ness two threads of olivine-dolerite, respectively 3 inches and 3 to 4 inches in thickness, traverse the Flags. Other threads, or the continuation of the last, 6 inches thick, are seen in the cliff on the western side of the Ness, 300 yards farther N.W. It is probable that these are fliers from a broader dyke of the same kind, though none such has been actually observed in the vicinity.

The westerly trend of the coast-line brings the Douglas Bay syncline once more into the cliffs at *The Whing*, 700 yards west of Little Ness, where, owing to the distortion of vertical folds, the dip of the flags swings to and fro between the top of the precipice and the bottom, as shown in fig. 40.

In the next recess and on the coast westward the general inclination is towards S.S.E., at an angle usually exceeding 60°. In the rocky spur towards S.S.E., at an angle usually exceeding 60°. In the rocky spur of Coolebegad some thick bands of pebbly grit and quartz-veined quartzite make their appearance, amid confused faulting and partial brecciation of the adjacent flags. They probably represent the northerly extension of the rocks of Santon (St. Anne's) Head (see p. 46 and p. 184). They are seen again at low water on the opposite side of the *Keristal* inlet, and pass obscurely, amid faults, into the cliff of the eastern shoulder of Port Soderick. The small 'greenstones' of this part of the coast are too numerous for detailed notice. In the centre of Port Soderick an olivine-dolerite intrusion, only about 4 inches thick, strikes north-westward across a foreshore composed of contorted strongly banded flags which dip towards S.E. at about 35°.

We have now reached the southern edge of 6-inch Sheet 13, the limit adopted for the Central division of the Island: the more southerly portion of the eastern coast will be described on subsequent pages (pp. 182-4), and we will now discuss the interior of the Central division.

Interior of the Central Division.

(6-inch Sheets 9, 10, 11, 12 and 13.)

The description of the area bordering the west coast north of Peel (N.W. portion of Sheet 9), supposed to be underlain by the Peel Sandstone, will be found in Chapters IV. and IX. (p. 277 and p. 457). To the eastward of this tract the Slate Series rises up in a range of steep slopes suggestive of an ancient sea-margin. The crest of the slope, from Knocksharry southward to Poortown, seems from the debris in the soil to be occupied chiefly by thick-bedded quartz-veined grits, which are however actually seen only in a few places, in the corners of fields between Lhergydho and Rockmount. The grits are flanked on both sides by variable banded flaggy slates of the usual 'unseparated' type. Except for the intervention of another thin strip of grit, unsatisfactorily exposed around Ballavaish and Staarvey, these slates extend eastward up to the belt of Barrule Slate through which the Neb has carved its cañon-like valley. An isolated hillock of banded slate with gritty intercalations rises above the low drift-plateau to the westward of the railway near *Peel Road Station*, like an outstanding Stack of the old shore.

The chief interest of the district centres in the size and variety of its igneous intrusions. At Lhergydho (near the northern margin of Sheet 9),

a quarry has been opened by the side of the road adjoining the farm in a mass of altered grit-like rock whose igneous origin was only recognised after careful petrographical examination of selected fragments (see p. 317). It seems to be a microgranite, but different from either the Dhoo or Foxdale types. As most of the ground in the district had, however, been surveyed before the true character of this rock was discovered, it is possible that slight outcrops in other places may have been overlooked or mistaken for grits. The intrusion appears to strike N.N.E. across the road, but its boundaries are obscure. It is probably *older* than the above-mentioned granites (see p. 319).

POORTOWN.

A mile farther south, we encounter the largest basic intrusion of the Island. Where best exposed, in a large quarry on the north side of the high-road at Poortown, $\frac{1}{4}$ mile east of Peel Road Station, this is a handsome dark-green porphyritic rock crowded with augite crystals, which has attracted the attention of many previous observers (see p. 304). Two hundred yards farther east, in smaller quarries on both sides of the road, much finer-grained material is revealed, in contact with baked splintery flags; and this material has been considered, on petrographical grounds, to be a separate and newer intrusion,¹ but the field-evidence is more favourable to the view that it is simply the more quickly cooled margin of the coarser mass. The igneous rock may be traced E.N.E. across the fields, by ploughed-up fragments and by small openings made for fencing material, in a belt 100 to 200 yards wide, extending for 700 yards from the quarries to within a short distance of the road to Lhergydho, 250 yards N. of Rockmount farm; and wherever seen it is fine at the margin and coarse in the interior as in the exposures in the quarries. Its extension northward from Poortown (see one-inch map) is somewhat problematical, the only evidence being the presence of rock-fragments in the ploughed fields, which cannot be explained by glacial agency. The westerly boundary of the intrusion is obscured by drift, but the coarsely crystalline character of the rock where last seen in this quarter indicates that it may once have extended for some distance farther, though now probably truncated by the prolongation of the eastern boundary-fault of the Peel Sandstone. Its easterly boundary is also obscure, and may be dependent upon another north and south fault, perhaps a branch of the above-mentioned, since in the road-cutting 300 yards S.S.E. of Rockmount the slates are shattered and decomposed as if by a line of dislocation; some pinkish ashy-looking felspathic bands in this cutting deserve remark, though too decomposed to yield much information. In its original shape the intrusion was probably a lens-like sheet inclining north-westward. There can be little doubt that the mass is connected with a chain of smaller intrusive bosses of nearly similar composition which ranges from N.N.E. to S.S.W. in this part of the Island. To the northward we find scattered links of this chain in some low slightly quarried outcrops, extending for about 100 yards, in the fields 600 yards N.N.E. of Ballavaish Moar (near the northern edge of Sheet 9), and in the exposures at Cronk y Voddee previously described (p. 137). The southerly prolongation of the chain, south of the Neb, will be subsequently noted.

A small quarry in a field 150 yards west of the road rather over half a mile north of Staarvey reveals a characterless rock which, if not a weathered grit, may be allied to that of Lhergydho. To the eastward of Glen Helen, bosses of pale rock of felsitic aspect, almost certainly of igneous origin, are exposed close by the farmstead of Eairy Moar, and in a small quarry 400 yards farther due S., just within the mountain-fence enclosing Beary Pairk.

BASIN OF
THE NEB
NORTH OF
ST. JOHN'S

The Neb has no doubt at one time reached the central valley through the dry gap at Ballacraigne, where the high-road turns off to the northward. By the present westward deflection of the river at Ballig, *Cronk Grianagh*, a rocky hillock of Barrule Slate, is left between the old and new valleys, like Cronk Sumark at Sulby, to guard the entrance of the Glen. Above the bend, in the part of the valley known as *Glen Moar*, we find

¹ see B. Hobson, Quart. Journ. Geol. Soc., vol. xlvii, p. 449.

good exposures of Barrule Slate in some extensive slate-trials on the western slope, while the eastern hill-side is drift-covered for more than a mile. In the crags to the westward of the approach to Glen Helen a small greenstone dyke is visible. The bottom of the valley in this and the higher portion of its course begins to show the banded unseparated rocks in places; and above the much visited waterfall of Rhenas (western edge of Sheet 10) the stream flows over striped rather sandy flags, with a general N.W. dip, resembling the more slaty portion of the Lonan Flags; but a mile farther up it again enters the Barrule Slates. Above Glen Helen the river receives no feeders on its western side, but on its eastern is joined by four important tributaries flowing W.N.W. in regular parallel courses. The beds of these streams for the most part show bare rock, and they afford practically the only opportunity for studying the upper basin of the river, the intervening moorland ridges being mostly drift-covered. In going eastward up *Blabae River* the more southerly of these streams, we continue for 500 yards on the striped slaty flags; then cross a belt of dull black welded slate 300 yards wide, perhaps a subsidiary infold of the Barrule Slate; then striped flags again for 300 to 400 yards; then flaggy grits, somewhat massive, with thick partings of slate; and finally striped flaggy slates once more; but in no case are the boundaries of these divisions well defined.

The same sequence is repeated in the next stream to the northward, which flows past Ballashimmin. This, however, reaches back farther east than the last, into a higher belt of grits; and then into the crush-conglomerate described in the last chapter (p. 58). In the next two glens, *Glion Gill* and *Rhenas River*, the exposures are not sufficiently continuous to reveal the succession. In all the streams, while the general dip is N.W. or W.N.W., local reversals to the opposite quarter are occasionally found, especially in the gritty rocks. This belt of 'unseparated' rocks seems to represent the prolongation of the beds forming the Sartfell and Slieau Curn ridge; and, as in that area, igneous intrusions, at any rate in a form recognizable as such, are of rare occurrence.

Rocks of the same general character occupy the hills bordering the basin on the eastward, including *Slieau Maggle*, Colden Mountain, Lhargee Ruy, Slieau Ruy and the greater part of Greeba Mountain (Sheets 7 and 10); and extend over the watershed to the heads of the streams draining into the River Glass, up to the principal belt of Barrule Slate on Beinn-y-Phott, Garraghan, and Creg Awhallan. On crossing this watershed, however, we come within the range of the intrusions which were conspicuous in the Crammag and Lhergyrhenny tributaries of the Sulby River (pp. 138-9). These are well exposed in the bed of Injebreck River, a feeder of the Glass, where examples of the Foxdale microgranites and of the altered greenstones are visible at several points, from 200 to 900 yards W. of the hotel. East and north-east of Injebreck, also, in the upper reaches of the Glass, small outcrops of altered actinolitic basic dykes are seen 60 yards below the old lead trial and 200 yards above it, and more extensive exposures in the banks of the side glen leading off to the eastward, 700 yards above the mine. At the head of the last-named little glen, there is a seam of soft clayey material which is probably a decomposed dyke; and another similar band occurs in the north fork of Colden River, where there are indications that the original rock was a microgranite. Other intrusions of the 'greenstones' were observed in the upper part of the crags of Garraghan overlooking the Glass Valley; in the bed of Colden River, 20 yards below the bridge of the mountain-road; in The Creg, 400 yards S.W. of the old slate quarries, and on the rocky slope 300 yards farther W., above *Awin ny Darragh*; in *Braid ny Scurrag*, at the head of the Awin; on the crest of Lhargee Ruy, 800 yards S. of the junction of the boundaries of the parishes of Braddan, Michael, and German; on the Slieau Ruy, at points 150 and 250 yards N.E., and 460 yards W. of the summit; and on Greeba, 50 yards S., and again 250 yards E. of the cairn.

Exposures of the microgranite or elvan type occur at intervals throughout the same range, again in such manner as to suggest that most of the outcrops may represent the displaced segments of a single dyke. Coming S.W.

HILLS
BETWEEN
THE BASIN
OF THE N.
AND GLAS
RIVERS.

from the above described example in Injebreck River, we find the proximity of an elvan indicated by debris at the roadside, 800 yards due E. of the summit of Colden (at "*Sheepfold*" of 6-inch Sheet 10). The same kind of rock, 10 to 20 feet thick, is visible at the source of the south fork of *Colden River*; and again, 600 yards farther to S.W., on the other side of the moorland ridge, at the head of a gully draining into *Awin ny Darragh*. The next exposure is a mile distant, on the very summit of Slieau Ruy, where the elvan is full of vein-quartz and is highly sheared, though not so greatly altered as farther south. A broad vein of quartz crops out on the hillside, 100 to 200 yards to the eastward, and there appear to be extraordinary complications in its vicinity, but the rock-exposures are scanty. Two hundred yards to the westward of the summit there is so much microgranite rubble in the old moorland path that we cannot doubt the presence of the elvan at this spot, though it lies quite out of the line of strike of the last exposure. On Greeba Mountain, 800 yards S.W. of the top of Slieau Ruy, we can trace the elvan for some distance on the crest of the western slope of *Braid ny Boshen*. It is here from 15 to 20 feet thick, and has been crushed in places into a platy schist. Interesting mineralogical changes, including the development of secondary garnet and chloritoid, which appear to be due to the crushing (see p. 318), may be observed in it in this neighbourhood, especially in the strip which forms low crags 500 to 600 yards farther south, or about 150 yards S.S.E. of the cairn on the summit of Greeba. Farther southward on the mountain no exposures of the intrusion have been detected.

The mode of occurrence of the bands of Barrule Slate on both sides of Greeba Mountain have been sufficiently described in the previous chapter (pp. 51-2); as also the presence of a wedge of grits near Ballagaraghan, between Greeba and St. Johns (p. 49).

SLOPES
NORTH OF
CROSBY.

Continuing eastward on the same parallel, north of the central valley (six-inch Sheet 10), we cross the structural axis where the sloping ground near that valley is chiefly drift-covered, with scanty rock exposures at intervals. Sandy flags, dipping E.S.E., are seen in a quarry at Crosby 150 yards N. of the main road; and in a few places in the drainage channels on the slope north of the village; and again in the little gully 150 yards east of the church; and in a similar channel crossed by the high road, rather over half a mile farther east. The slope has been strewn in many places with large boulders of beautiful actinolitic greenstone and microgranite, which are now built into the fences; but it remains uncertain whether these denote concealed outcrops in the neighbourhood or have been transported across the intervening ridge from the Baldwin basin by glacial agency (see p. 454).

On the crest of the slope, where there are several craggy outcrops of the sandy flags, a tough altered 'greenstone,' 10 feet wide, which would furnish useful road metal, is exposed on *Cronk Breac* 150 yards N.W. of Braid, along with a second dyke, 6 feet wide, of similar material greatly sheared, 180 yards farther to N.W.

VALLEY OF
THE GLASS

In descending into the valley of the Glass or West Baldwin, above its junction with the Baldwin or East Baldwin stream, we cross the most southerly recognisable outcrop of the Agneash Grits on the steep slope north of Mount Rule (see p. 41). At the right-angled bend of the river north-west of this exposure we pass onto striped greyish sandy rocks with occasional grit bands, left as unseparated on the map, but much resembling the Lonan Flags; and the same type continues to predominate nearly up to Injebreck, so far as one can judge from the places not covered by the drift and alluvium with which the valley is encumbered. The same conditions are also found in the lower portion of *Awin ny Darragh*.

At Ballachrink, in the little ravine of a small feeder, 50 yards west of the main stream, a broad elvan of the Foxdale type, seemingly the prolongation of the great Crosby dyke (p. 168), is revealed; and is repeated in the same gully 80 yards farther westward a little below the high road; and again where bare rock is exposed at the farmstead just above the road. In the main glen three-quarters of a mile farther up-stream, 500 yards N. of the

junction with the *Darragh* at Baldwin, a much crushed mass of pale felsitic rock occurs in the river-bed, but the identity of this material with the elvan has not been established.

Two smaller dykes of a more basic type are visible in the stream within 100 yards north of this place; and above this there is little to see in the valley except drift and alluvium until we reach Injebreck. The old lead trial on the east bank at Baldwin is described at p. 543.

On the cultivated ridge between West and East Baldwin the only notable outcrop of solid rock is on *Cronk y Keeill Abban*, the site of the old Tynwald, north of St. Luke's Church. A small quarry 300 yards N. by E. of the Church is opened in dark blue spotted altered slate; while on the steep brow to the westward a crush-conglomerate of sandy slate is sparingly exhibited, and also a greenstone dyke, about 8 feet in width.

The parallel valley of East Baldwin contains little that is noteworthy until we gain its upper reaches. As a rule the country-rock is more gritty than in the sister-stream, and above Adderry and in the Creg-y-cowin tributary quartz-veined grit-bands of the Agneash type are frequently exposed, with their slaty partings often speckled with secondary minerals and frilled with intersecting cleavages. The prevalent dip, as in West Baldwin, is usually to N.W. or W.N.W., but the beds are often nearly vertical. At Ballawyllin the dismantled "Ohio Mine" (see p. 543) adds one more to the list of abortive searches for lead in the central part of the Island.

Along the western edge of the Agneash Grits the metamorphism both of the country rock and of the basic intrusions reaches its maximum. Small highly altered greenstones are exhibited in three places in the bed of the main stream near the Dhoon farmstead; and again in the gully of the little feeders north and south of this place; and in *Glion Feeagh* the west branch of Baldwin River, 500 yards north of Dhoon. In the east branch similar outcrops are seen, 300, 400 and 800 yards above the fork, the last being distant only 200 yards from the exposure on the lower slope of Beinn-y-Phott to which attention has already been called (p. 139).

The high ground forming the watershed between the Baldwin and the Laxey basins in Sheet 10, south of Mullagh Ouyr, including Carn Gerjoil (1,430 feet) and Slieau Ree (1036 feet), is mainly composed of the highly contorted quartz-veined Agneash Grits, in which we find a prevalent tendency of the bedding towards W.N.W., but with numerous local modifications. Except on Carn Gerjoil and *Gob y Creggagh* three-quarters of a mile farther west, the exposures are not extensive; but there is no lack of minor outcrops. A small 'greenstone' intrusion is visible in one of these patches of bare rock, 1150 yards north of Balliaragey.

The south-eastern flank of the ridge is drained by the Abbey Lands or *Little Sulby* River. The sandy and slaty flags over which this stream flows are continuous eastward with the Lonan Flags of the coast, and are shown on the one-inch map as part of that division. It must be acknowledged, however, that there is little or no difference to be noted between them and the 'unseparated' rocks of the West Baldwin valley (see p. 39). The lower part of the stream nearly coincides with a sharp synclinal trough in the flags. In its higher portion the common direction of dip is to N.W. or W.N.W. at high angles; but the inclination of the cleavage is in the reverse direction, or toward E. or E.S.E., as usual on the eastern side of the central axis. In the rising ground between this stream and Groudle River wherever the flags are exposed, as at Gob-na-geay, *Glenchoo*, Cronk-ny-mona, etc., both their bedding and cleavage planes dip south-eastward.

The deep hollow between Carn Gerjoil and Mullagh Ouyr is drained by a number of small streams which unite and flow into Glen Roy a mile above Laxey. Above their union the beds of these streams usually reveal gritty flags, which though mapped with the Agneash Grits might with almost equal reason have been placed with the Lonan Flags, their smoothly waterworn and often moss-covered surfaces scarcely affording adequate evidence for discrimination between gritty flags and flaggy grits. The

VALLEY
OF THE
BALDWIN

EASTERN
RIM OF
BALDWIN
BASIN.

GLEN ROY
AND
FEEDERS.

prevalent dips are towards N.W. or W.N.W.; but between the union of the rivulets at *Ballachoon* and the junction, a half-mile below, of their combined stream with Glen Roy, the inclination of the greatly crushed and welded flags swings round to the exceptional direction of W.S.W., indicating a westerly pitch of the composite folds of the central axis in this neighbourhood. Some traces of basic igneous intrusions may be detected in this quarter, but they are so crushed and altered as to be scarcely recognisable in the insufficient outcrops.

Better exposures of the dyke-rocks, including the Dhoon microgranite elvans, are found nearer the headwaters of the individual streams. In the most easterly of the streams these are visible in four places, in a distance of 400 yards between the head of the west fork and Close Mooar. A broadish dyke of tough 'greenstone' is revealed in the same stream, 250 yards due S. of Close Mooar. Other exposures of microgranite occur in the gutter descending from the col between Carn Gerjoil and Mullagh Ouyr, 200 to 400 yards east of the Douglas and Snaefell high road; and on the same hillside one-third of a mile farther east, at the corner of the fence of an old enclosure, 100 yards below the cross road to Laxey. These are the most southerly localities at which the elvans of this group have been recognised with certainty. If continued along the same strike they should be found in the same district as the Foxdale elvans in the Baldwin basin, but they have not yet been recognized there. Their discovery in this area might afford data for determining the relative age of the two granites (see p. 312); and a careful re-examination of the Baldwin valley with this point in view might possibly be successful, as dykes were observed in that locality, the relations of which have not been definitely established (see *ante* p. 159).

In the upper part of Glen Roy only two or three small dykes of greenstone were noticed. A small quarry behind the buildings of the old mine (p. 529) exhibits an intrusion of greenstone 15 feet or more in width, and large blocks of the same rock are scattered on the steep hillside S.W. of this place. Below the mine the sedimentary rocks resemble in character and complexity of structure those already described in the lower part of the tributary glen. Four small 'greenstone' dykes were observed below the junction of the valleys, at the distances, respectively, of 500, 900, 1,200 and 1,750 yards above the main-road bridge in Laxey village.

STRICT
L. OF
EN ROY;

The watershed south of Glen Roy (Sheets 10 and 11) coincides roughly for some distance with the parish boundary between Lonan and Onchan. It consists of a moorland ridge occupied by the weathered Lonan Flags generally thinly covered with rubble and wash, but with frequent exposures of bare rock. It is curiously channelled in places by transverse hollows excavated in the rock, probably by streams from the waning ice-sheet (see p. 363). On Slieau Meayl, the westerly part of this ridge, there is a rather good exposure of an altered dioritic greenstone, about 10 feet wide, in the low crags a few yards beyond the mountain-fence 800 yards N.E. of the Craig-ny-Baa Inn on the Snaefell road, which may represent the same intrusion as that above-described at the Glen Roy Mine. Traces of other smaller greenstone dykes were observed farther east, on the moorland N. and N.E. of *Injaign* and in the old road down the ridge between Cooil Roi and Barroose.

There are indications that in the neighbourhood of *Caunrhenny* (Sheet 11) one-third of a mile N.E. of Ennemona, the outcrop of a more important intrusion, of somewhat unusual type, may be concealed by the thin drift and rubble. Blocks of a pinkish micaceous rock, perhaps a mica-trap like that of Port Groudle, are common in the fences; while the soil in the cultivated land 120 to 200 yards due S. of the farmstead is full of similar rubble which can scarcely have been derived from the glacial deposits of the neighbourhood, and probably denotes a subjacent outcrop.

OUDDLE
VER.

The bed of Groudle River and that of its parallel tributary, the *Ballacottier River*, lie entirely within the Lonan Flags. There is much drift in the upper part of the basin, but below the junction of the streams

the valley-slopes are chiefly of rock. The prevalent dips in both streams, northward of Clypse, are steeply north-westward; but from their junction to the sea the general inclination is equally steeply in the opposite direction, the beds being nearly vertically folded in a few exposures in the intervening belt. Two small greenstone dykes were noticed on the N.E. side of the valley, $\frac{1}{2}$ mile above *White Bridge* where the main road from Douglas to Laxey crosses the stream.

The picturesque gully cut deeply in solid rock, in which a feeder from the north joins the main stream in the enclosed pleasure-ground near Groudle Tramway Station, is a typical Manx post-glacial ravine. It might be made to afford a rough measure of the time which has elapsed since the disappearance of the ice-sheet. In the bed of this feeder, $\frac{1}{2}$ mile above the junction, and in the adjacent tramway cutting there is an exposure of massive quartz-veined grits like those of the north side of Clay Head (p. 152); and the same belt appears to be continuous in the opposite direction, as shown on the map, to *Port Jack* (p. 153).

A peculiar dyke, unfortunately much decomposed, is exhibited in a cutting at Garwick $1\frac{1}{2}$ miles farther north, just before the tramline crosses *Glen Gawn*; it consists of a pale yellowish-grey felsitic rock speckled with the short rods of a secondary chlorite (p. 317).

On Banks Howe (Sheet 14) the cuttings of the same line reveal excellent sections of the Lonan Flags, with the rock-surfaces scored in many places by glacial striæ. The intrusive mica-diorite of this locality has already been described (p. 152).

In the lower part of the valley of the Glass, in the neighbourhood of **LOWER Tromode** (Sheet 13), a thick mass of till has blocked the old channel in **PART OF** glacial times; and during re excavation, the stream has for a time missed its **THE GLAS** former hollow, and notched a new ravine for itself in the solid rock of the **VALLEY.** western bank 400 yards above Tromode Mills. Afterwards, erosion at this point not having kept pace with that in the drift-filled channel above and below, the river recovered its old course and abandoned the gap, leaving a steep isolated hillock of rock between its former bed and its present channel. As in several similar instances in the Island, this hillock was converted into a rude fort by the ancient inhabitants.

On the opposite or eastern side of the valley there is another dry channel of higher level and older date, probably dating back to the close of the Glacial period; this makes a larger loop under Ballanard and rejoins the present valley at Tromode.

In the striped flaggy slate immediately to the northward of the bridge at Tromode, a small weathered basic dyke is exposed. Four hundred yards south of the bridge, a little below the lodge of Cronkbourne House, a much broader intrusion is visible in the bed of the stream; though so much decomposed that most of its characteristics are lost, this probably belongs to the diorite group.

Another small greenstone dyke is revealed in the low outcrop of slaty flags where the stream impinges upon the base of the steep slope at the southern border of the alluvial flat opposite *Purt-ny-shee*.

The sloping ground above the valley on either side is smoothly drift-covered and under cultivation, with only a few isolated artificial rock exposures which need no comment.

The remaining portion of our central division lies to the southward of the Peel and Douglas valley, and this tract will be next described, commencing as before, in the west and working eastward.

Hills south of Peel.

The hilly ridge of *Niarbyl* Flags bordering the coast south of Peel is simply the extension of the rocks seen in the cliffs (p. 146), and needs no further description. An excavation has been made into the west bank of the *Neb*, at the foot of the inland slope of Peel Hill a quarter of a mile south of Peel Railway Station, to obtain decomposed slate for brick-making. This material is covered by a variable thickness of rubbly drift; its rotten condi-

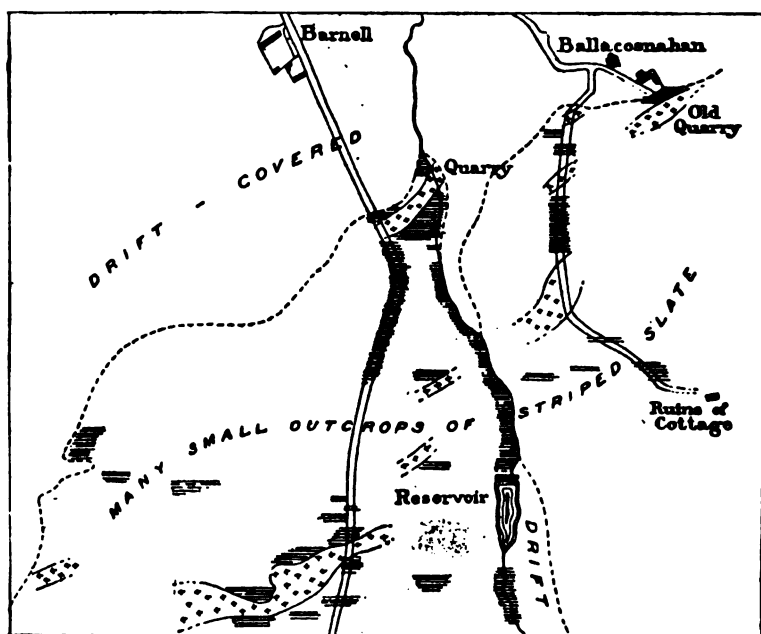
tion may be due to ordinary weathering, but is more probably connected with crushing or faulting along the margin of the Flags. The interesting exposures of red conglomerate in and adjacent to the river-bed near Glenfaba Mills are described in Chapter VI., p. 278.

3K
FRICK.

Between these Niarbyl Flags and the Barrule Slates of Slieau Whuallian and Arryse Hill we find a belt of 'unseparated' palish blue striped slates, phyllites, etc., like those of the coast south of the Niarbyl, with an apparent

FIG. 41. *Plan of irregular outcrops of greenstone south of Barnell, Kirk Patrick.*

Scale, 6 inches = one mile.



The greenstone outcrops are indicated by crosses, and the slate outcrops by horizontal lines.

dip towards N.N.W. Associated with these rocks are many crushed lenses of basic igneous material, which occur in the same zone of intrusion and are similar in composition to the Poortown diabase, though differing from it in being usually highly sheared and less coarsely crystalline.

The chief outcrops of these intrusions are found on the steep slopes southward of *Barnell* and *Ballacoshahan* (Sheet 9), and appear to denote the existence either of a number of independent bosses or of a single mass broken up into disconnected blocks, the exposures, as shown in the above reproduction of the six-inch field-map, being insufficient to determine the point.

The shearing of these bosses has, in some instances, produced a platy schist around their edges; while in others—for example, in a small quarry behind the farmyard of *Ballacoshahan*—the whole mass has become schistose by the development of shear-planes parallel to the cleavage of the surrounding rocks. Smaller dykes of similar composition and structure occur in several places east of the localities shown in the above plan, as for instance, in the old slate trial on the N. slope of *Slieau Whuallian*, 400

yards south of the highroad at Glenaspert, where two bands of greenstone-schist respectively about 4 and 6 feet in thickness are exposed.

The slopes between Ballacossnahan and Glen Meay are enclosed and cultivated, and although the rock is usually near the surface the actual outcrops are few and limited. Indications of the intrusions may however be observed in two parallel roads 400 and 550 yards south of the more northerly houses of Rheabybeg, and in the bed of the gully draining thence westward to Rheahymoar. On the opposite or south side of Glen Meay, along the same strike, a mass of similar material of considerable thickness is just visible in an old quarry on the hillside above Ballachrink, 150 yards S.E. of the farmstead; and again a 'sheared camptonite' (p. 308) may be seen in the bottom of Balleby Glen 600 yards east of the highroad (Sheet 12). On the hill-top, $\frac{1}{2}$ mile farther east, there is an outcrop of 'greenstone' in a field 150 yards east of Magherbane; while a little to the southward of Dalby other examples occur in the field-road leading up the hillside opposite Ballacain, and in a little quarry by the side of the main road 300 yards farther south, behind an old cottage. The last-mentioned instance may however be of a different type from the others. In several other places, particularly in the upper part of Glen Meay, small dykes of obscure character were observed, but scarcely require special notice.

The small outcrop of andesitic breccia at Ballnalargy or Ballaquane, half a mile N.E. of Dalby Church, is especially interesting as furnishing the only known occurrence of true volcanic material in association with the Manx Slates (see *ante*, p. 38 and *post*, p. 323). The rock was first noticed in the occupation road which adjoins the rivulet opposite Ballaquane farmstead, 150 yards east of the highroad, and was then traced into the neighbouring field on the west, where it breaks above the surface near the ruins of a cottage, and has been recently better shown in a shallow excavation for stone. It seems to extend at least as far as the north-west corner of another field 100 yards south of the old cottage, but the scanty outcrops fail to reveal its further course, or its relation to the adjacent flags. There are some rather extensive rock exposures in Balleby Glen, only 300 yards farther southward; but neither here nor in any other part of the district has the breccia been recognised. It unfortunately happened, however, that the survey of the Island had been completed before the true character of the rock was established, by the microscopic examination of fresh specimens from the above-mentioned excavation, so that there is a possibility of small outcrops having been overlooked which would now be recognised. Further search for it in Balleby Glen and Glen Meay might prove more successful.

ANDESITIC
BRECCIA
NEAR DALBY

The chief physiographical features of the Glen Rushen drainage-system have already been discussed (p. 10). The precipitous walls of the ravine by which the river escapes to the sea at Glen Meay are composed of Niarbyl Flags. As previously stated (p. 148) a conglomerate is mentioned by Harkness and Nicholson as occurring in the "Skiddaw Slates" of this locality; but the only conglomerate now visible here is a fault-breccia in the southern wall of the ravine a little below the ruins of an old lead trial. A small outcrop of brecciated rock in the same bank above the mine, under the farmstead of Ballacrink, which was at first thought to resemble the andesitic breccia above described, also proved, on microscopic examination, to be made up of crushed sedimentary material. Farther eastward, in the fine valley by which the stream crosses the outer belt of Barrule Slates, broad segregation veins of quartz are conspicuous. These have been dragged apart into discontinuous segments, after the manner of the intrusive dykes, their interrupted courses usually following the general strike of the country-rock. Determined attempts have been made to win roofing slate in this valley, and the slopes are deeply scored, especially on the S.W. side, by old quarries (see pp. 560-1). In following up the stream, we leave the Barrule Slates at the great bend above the quarries, the valley-floor above the bend consisting of slaty flags, changing gradually to flaggy grits which then continue nearly to the head waters.

GLEN
RUSHEN.

The Barrule Slates meanwhile occupy the rounded ridge of Dalby Mountain on the west of the Glen, and also the elevated eastern and southern rim of the basin, forming the hill chain extending from Cronk ny Arrey Lhaa to South Barrule; and the manner in which the two belts converge at the higher levels toward the source of the stream suggests that they have formed a single mass overlying the flags and grits until separated by the erosion of Glen Rushen.

At Chleig-fleeiney (of 6-inch : Chleig Cheeiney of 1-inch map) there is a belt of massive coarse grit like that of the shore at Gob yn Ushtey; but usually the gritty flags of this valley bear more resemblance to the arenaceous portions of the Niarbhl Flags than to the quartz-veined grit of Agneash and of the south of the Island. N. to N.W. dips prevail throughout the valley.

The old mines on the eastern slopes of Glen Rushen were worked on the westward prolongation of the Foxdale lode and have yielded large quantities of silver-lead ore (see p. 504). In spite of numerous trials on the opposite slopes and on Dalby Mountain, the lode has not been recovered among the Barrule Slates to the westward of the Glen; and it is noteworthy that there is no instance in the Island of the occurrence of profitable ore-bodies in this division.

XDALÉ
SIN.

The chief belts of rock in Glen Rushen may be traced along their strike, over the ill-defined watershed, to the western side of Foxdale; but either because of the lower average level of the ground beyond, or perhaps from structural complications connected with the granitic intrusion, they cannot be followed with any certainty to the eastward of Foxdale.

In coming up this valley from St. Johns, we have the steep gable end of Slieau Whuallian on our right, and a cultivated slope of much lower elevation on our left. A rocky hillock which breaks the latter slope opposite to Kennaa is composed of thick obscurely-folded bands of dark-bluish muddy pyritous grit with slaty partings, quarried for road-metal. These bands strike N.E. across the central valley and probably reappear on the opposite side in an old quarry 200 yards S.E. of Ballagaraghan, and again in the bed of *Greeba River*. To the westward of Foxdale, however, they have not been identified. Above Ballacates, two or three hundred yards farther up the slope, dark blue slates of Barrule type are exposed, and have been tested for roofing slate in a small trial. These slates also extend up to the central valley, occupying the hill top at Kerrowgarroo (509 feet) and the lowermost part of *Glen Darragh* near Ballacurry. Though now interrupted by the central valley, they have probably been continuous with the wedge which lies on the western slope of Greeba Mountain. Their extension in the opposite or south-westerly direction is more or less doubtful; but, as shown on the one-inch map, there are rocks of this character in Foxdale around Ballanass, apparently wedging out rapidly westward. Some veins of quartz (with a little mica and chlorite) by which these slates are penetrated are of exceptional breadth; one example, 10 to 12 feet wide, has been quarried on the northern slope of Kerrowgarroo, 250 yards S. of the railway.

To the southward of this tract of Barrule Slate there is an unsatisfactory area of 'unseparated' banded slaty rocks, broken by the Foxdale granite; and the same type extends thence, with minor variations, over the greater part of the interior south of the central valley and east of the main hill-range of the Island.

ETAMOR-
IC AREA
OUND
CHAL-
GAN.

In the Foxdale depression these rocks do not show any greatly increased degree of alteration until they come into close proximity to the granite. But on the higher ground to the eastward, around the heads of *Glen Darragh* (of Sheet 9; commonly known as *Ballacurry Glen*) and *Cooillingill*, and upon *Archallagan* hill, although the visible outcrop of the granite is about a mile distant, the metamorphism is more excessive than in any other part of the Island, the slates being converted into garnetiferous mica-schists. These phenomena have already been discussed, in Chap. III., pp. 111-2, where the chief exposures of interest are indicated.

PPER PART
FOXDALE
SIN.

The western bank of the Foxdale stream opposite *Ballamoore* (Sheet 12), two-thirds of a mile north of Foxdale mines, reveals a 5 ft. dyke of micro-granite, sheared to the condition of horny-looking schist; a similar exposure

occurs on the opposite bank 400 yards farther up stream; and possibly a third, in an all but unrecognizable condition, 350 yards beyond. The rocks in these exposures differ in some respects from the usual Foxdale elvans (see p. 316); and it is possible that they may not be directly connected with the main mass of the Foxdale granite, but with the concealed intrusion which was encountered in the deeper levels of the old Cornelly or Townsend lead mine (marked 'Old Mines' on one-inch map) at the head of Glion Darragh, $1\frac{1}{4}$ miles farther east (see p. 516). Two or three small elvans of similar character occurring in *Glion Darragh* may belong to the same group.

The exposures in the valley below the Foxdale mines are greatly obscured by the washing floors and spoil heaps; but the destruction of the natural sections is amply compensated by the artificial sections of the mines, which are elsewhere described (see pp. 504-12). In these mines the underground extension of the granite northward with a gradually shelving surface is clearly demonstrated.

Foxdale Granite.

The most northerly surface outcrop of the granite occurs in the bed of the stream 100 yards above the washing floors of the mine. Two hundred yards farther N. a short adit driven westward into the bank of the stream passes sharply from granite into slate through a crushed junction, perhaps a small fault, within ten feet from the entrance; and a few yards farther up the gully, a wedge of slate, traversed by an elvan, encroaches upon the granite, and occupies both banks of the stream. Hence we may conclude that the western bank of the hollow nearly coincides with the western boundary of the granite. Small quarries in the slate, combined with a natural section at a cascade in the stream close by, afford opportunities for studying the aforesaid elvan and the junction of the sedimentary rock with the granite. The slate is highly altered, but not to the same degree nor in the same manner as in the garnetiferous schists of the Archallagan track above described. Above the cascade the stream bed (*Struan Barrule* of six-inch map) is again composed of granite, but the solid rock is soon lost under a covering of rubbly wash and drift.

The main mass of the granite occupies the rounded hill to the eastward of the stream, named "Granite Mountain" on the ordnance maps, but known in the early part of the century, according to Henslow,¹ as *Slieau ny Clough* (Clagh ?). The intrusion has a rudely oval outline, with the longer axis, five-sixths of a mile in length, extending E.—W. as in the Dhoon Granite, and its shorter diameter, quarter to half a mile, N.—S. Though its northern edge is nowhere actually visible, its position may usually be determined within a few yards by the character of the surface-rubble; and there is a small quarry in slate close to its margin, 600 yards E. of the stream. In this quarter a broad off-shoot of granite appears to strike N.W. into the slates, being slightly exposed by the roadside near the new cottages at the foot of the hill, and more clearly in the channel of the sluice 100 yards farther to N.W., having in the latter case a thickness of more than 20 feet. Following round the boundary south-eastward, we find a small opening, revealing much-altered slaty flags traversed by a thin elvan, close to the eastern margin of the granite 500 yards W. of Renshent. Then turning westward, we can follow only an approximate boundary across the boggy moorland north of Cloghwillly until we reach the top of the hill, where small outcrops are sufficiently numerous to allow the detail of the margin, with its fringe of apophyses, to be traced. Some old slate quarries on the western brow of the hill afford further opportunity for studying the alteration of the country rock adjacent to the intrusion. The edge of the granite 150 yards to the eastward of the larger quarry takes the form of a sloping plane, somewhat crushed and platy, and marked with slickensides, as though there had been a slight overthrusting of the slate upon it at this point.

¹ Trans. Geol. Soc., vol. v., p. 485.

Within its margin the granite presents many variations in texture, being seamed in places by thin bands of finer material resembling the elvans. This feature is referred to by Cumming, who seeks to explain it by supposing "a second elevation of the granitic mass, during which were injected into the cracks and fissures then formed those elvans or granitic veins which we find penetrating far into the schists round about this boss, three of which are cut through in the Foxdale mine."¹ But besides these veins of finer material, there are others of pegmatitic character, more coarsely crystalline than the surrounding mass. The granite is also traversed by gashes filled with quartz accompanied by small quantities of yellow mica and other minerals, which are considered by Harker to be of the nature of greisen² (see p. 320). The more conspicuous of these quartz-veins have a N.N.W. strike; the largest, having a breadth of 10 to 15 feet, has been extensively quarried on the northern side of the hill 700 yards E. of *Struan Barrul*. Similar veins occur among the slates beyond the boundaries of the granite; a good example is exposed in a small quarry at Cloghwillilly 300 yards S.E. of the S.E. corner of the granite. The petrographical description of the granite is given on p. 315.

Besides the main outcrop on Granite Mountain, a small outlier of the intrusion comes to the surface on the patch of moorland to the eastward of Renshent, 500 yards E. of the edge of the principal mass. The intervening tract is occupied by slate which is exposed, in a much altered condition, in several places in the bed of the rivulet draining the eastern slope of Granite Mountain; and in Santon Burn, the parallel stream, 200 to 300 yards farther east. The slate is of the striped flaggy description and its dominant planes (cleavage or bedding) in Santon Burn exhibit a somewhat unusual dip towards S.W., but swing round to S. and S.S.E. on passing away from the neighbourhood of the intrusion. The granite outlier is poorly exposed, and its actual boundaries are nowhere visible; but its maximum dimensions seem to be about 300 by 200 yards. It contains much vein-quartz, which is excavated in small quarries; the granite itself wherever seen is much decomposed, but similar in general characters to the main mass.

It is not clear whether this outlier represents the top of a boss rising up from the shelving surface of a concealed portion of the intrusion continuous underground with the mass to the westward, or whether it is a block which has been separated from the larger body by faulting, overthrusting or other effect of earth movement. The known inequalities of the surface of the granite as revealed in the shafts of the Foxdale mines favour the first supposition; while the absence of granite in the East Foxdale mine only 350 yards N. of the outlier (see p. 514), and from the other workings between this place and Foxdale (p. 513), along with the indications of disturbance in the belt of slate separating the outlier from the main outcrop give colour to the second view. Prior to the examination of the ground by the Survey the isolated character of this patch of granite does not appear to have been noticed.

Unlike the dykes from the Dhoon Granite, the chief elvans of the Foxdale type cannot be traced directly into the intrusion, but strike past it among the slates some distance to the southward; while those apophyses which are seen to spring from the margin of the intrusion appear all to die out within a short distance of their source. It is noteworthy, too, that although the granite has been proved in the mines to shelve down gradually northward, the exposures of elvan-material in that quarter are few and small, while to the southward they are many and large. Thus, in going south from the main boss along the heather-covered moorland strewn with glacially transported blocks of the granite, we find indications of elvans at several detached points within $\frac{1}{2}$ mile of the margin of the intrusion; though the chief examples occur near the end of the ridge, on *Windy Common*, a little more than $\frac{1}{2}$ mile from the granite.

In their mode of occurrence these elvans resemble the other Pre-Car-

¹ "Isle of Man," p. 175 and section on pl. I.

² A. Harker. *Quart. Journ. Geol. Soc.*, vol. li., p. 143.

boniferous dyke-rocks of the Island, being arranged in short tapering segments which appear to represent the broken and displaced portions of individual intrusions. The rock of which they are composed is pale yellowish close-grained felsite or micro-granite, characterized by sparsely distributed hexagonal crystals of white mica, but otherwise not readily distinguishable in the field from the finer grit bands, with which indeed they have sometimes been confused¹. They usually show more or less evidence of post-consolidation movement, and in a few localities have been reduced to platy schist, not recognizable as an igneous rock in hand specimens.

Westward from *Windy Common*, an exposure of micro-granite appears to be indicated by the large loose blocks in the bed of *Avin Ruy*, 700 yards due N. of Gibdale farmstead. On the westward prolongation of the same belt, an intrusion, probably over 30 feet wide, is seen in the highroad 300 yards farther W., close to a milepost (Sheet 12), and is less distinctly indicated in the old road parallel to the former, 300 yards beyond; after which it is lost for two or three miles under the sheet of drift which covers the upper basin of the Silverburn.

Nearer the granite, a smaller elvan, about 9 feet wide, with platy slate-like cleavage, is exposed 70 yards E. of the highroad at the next milepost (6 miles from Castletown), in the gutter draining eastward into *Struan Barrule*, apparently striking N.W., in agreement with the local deflection of the slates in this locality. It may be this dyke which is again revealed in the large old slate quarries on the north-eastern spur of South Barrule (*Barrule Beg* of 6 inch map), over half a mile farther west, where an elvan having a thickness of 8 feet occurs in one of the entrances to the quarry, but is pinched along a thrust-plane in the interior of the excavation into a pale schist only one to two feet thick, some thin veins of quartz being also implicated in the crushing.

The description of these elvans at their reappearance in the hills on the western side of the basin of the Silverburn and in the cliffs of the west coast has already been given; and an account of their outcrops farther south, in Sheet 16, will be found on p. 171. The first point of their westerly reappearance seems to be in a small old quarry on the eastern slope of Cronk ny Arrey Lhaa, 500 yards S.W. of the fork in the old mountain road leading from Port St. Mary to Dalby.

Returning now to trace these elvans eastward from *Windy Common*, we find the first exposure half a mile E. of that moorland, in a gutter 120 yards S. of Tosaby farmstead (Sheet 12). At *Campbell Bridge* which crosses the FOXDALE
ELVANS *Santon Burn* at Ballanicholas, half a mile farther east, micro-granite has SOUTH ANI
EAST OF T been penetrated in a small mining shaft; and from the abundance of this GRANITE. rock in the old fences of the neighbourhood it is probable the dyke has at some time been quarried at the surface. The next indication of the elvan is at Ballacallin Moorar, half a mile farther to N.E., where some of the farm-buildings are composed of this material, said to have been obtained from a small disused quarry in the adjacent coppice. As these exposures lie nearly in the same line of strike, they may represent a single intrusion.

The first outcrop of a more northerly set is found in an occupation road 50 yards S. of the most northerly house of *Ballachrink*, and only 300 yards W. of the granite outlier. The next indications are some small quarries, now overgrown, on the new enclosure on *Dreem-lang*, W. of Garth, which appear to have been in micro-granite. Thence the elvans may be traced at intervals N.E. down the slope towards Garth, by loose blocks or low crags, the best exposures being in the rough ground 200 and 350 yards N.W. of Garth farmstead. A portion of the intrusion has also been cut in a

¹ *E.g.* Clifton Ward described the Crosby Dyke as "a thick bed of quartzite," *Geol. Mag.* dec. ii., vol. vii., p. 3. Henslow, however, though he considered the fine sheared greenstones to be greywacke, called attention to the granitoid character of these "quartz-rocks." *Trans. Geol. Soc.*, vol. v (1821), p. 487.

mining level on the north side of the stream. The stones of the prehistoric monument, "St. Patrick's Chair," in an adjacent field, are detached slabs of this material. On the same strike, half a mile farther N.E., a single broad elvan is well seen in old quarries and in the roadway close to St. Runn's Church (Sheet 13). There is a gap of 500 yards of cultivated ground between this place and the next exposure in the well-known quarries at the foot of the hill opposite to Crosby Station (Sheet 10), where the whole width of the dyke—20 to 30 feet—and the adjacent walls of slate are laid open to inspection (see p. 315).

Other more northerly shreds of micro-granite, of small size, perhaps emanating from the boss touched in the Cornelly Mine (see p. 516), were observed in *Coillingill* stream, 1 mile due W. of Crosby (S.W. corner of Sheet 10). On the moorland to the southward, near the E. corner of Archallagan plantation, there seems to have been a small quarry, now overgrown, which has supplied similar material for the adjacent fences.

SLATES
AROUND THE
FOXDALE
GRANITE.

The sedimentary rocks in the vicinity of the Foxdale Granite show more indication of disturbance than do those adjacent to the Dhoon Granite, but it is not certain that their irregularities are due to the intrusion. The Dhoon Granite lies somewhat to the S.E. of the structural axis of the slates, whereas the Foxdale Granite breaks directly in upon this axis, where deviations from the usual strike are frequent even when the granite is not present. Hence the Foxdale mass may be coincident with rather than the cause of the deviations. At any rate the slates around the junction seem to have been already tightly folded before the igneous mass and its elvans were injected among them. At the same time, we have clear proof of later movement, which affected the granite and its elvans after their consolidation; so that it is very probable some minor local changes in the direction of the bedding and cleavage planes of the sedimentary rocks may have resulted from the yielding of the strata when pressed against the massive intrusion (see p. 316.) From whatever cause, the prevalent dips to the northward of the granite are towards N.W. or N.N.W., and to the southward of it are S.S.E.; while in its immediate vicinity they are much less regular, and show a general but by no means universal tendency to dip away from the intrusion on all sides.

BASIC DYKES
NEAR THE
GRANITE.

Greenstone dykes are not numerous in the neighbourhood of this granite, nor is the evidence so clear as in the case of the Dhoon granite to show that they are the older. Such is probably the relationship, however, as those which do occur are in the altered actinolitic condition. Three small examples in this state are exposed in the upper part of *Glion Darragh* (Ballacurry, Sheet 9), respectively 300, 350 and 500 yards N. of Cornelly Old Mines, where they are very difficult to distinguish from the highly altered flags and garnetiferous schists with which they are associated. Toward the mouth of this glen the rocks are broken by N. and S. dislocations which may be faults of some magnitude. In *Coillingill*, among altered country-rock dipping abnormally towards N.E. or E.N.E., a 3-feet dyke exhibiting beautiful sheaves of actinolite-needles crosses the stream 450 yards below the boundary-fence of *Archallagan* plantation; and a boss of somewhat different aspect crops out in the corner of a field on the hillside 350 yards to northwestward; and again, more obscurely, on the adjacent moorland 350 yards due south of Rhenny. A more extensive exposure is found in *Creg y Whualliam* overlooking the central valley S. of Grecha (Sheet 10), where an intrusion of actinolite-schist about 10 feet wide can be traced up the craggy slope; and is seen again near the angle of the fence bounding the cultivated land, one of its rock-faces bearing the inscription "*F. Moore bought this estet A.D. 1766. 1770.*" The upper part of these crags is composed of welded dark blue slate of the Barrule type, but towards the base we find a wedge of highly sheared grit-bands, with greatly-altered garnetiferous slaty intercalations. The locality lies upon the structural anticline; and the strata, as usual, strongly exhibit the deformation-phenomena of frilling, puckering, and stretching. The dark slates have a fissile shear-structure, dipping towards N.E. like the "stripe" of the altered flags in *Coillingill*; they appear to wedge out westward before reaching *Glion Darragh*.

SOUTHERN
SLOPE OF
CENTRAL
VALLEY.

In *Ellerslie Glen* (Sheet 13), dykes of altered greenstone are visible in the west bank of the old dam, and in the bed of the stream 200 yards south of the ruined lead mine. Another example occurs in the higher reaches of the same stream, 150 yards west of the bridge at Garth.

To the southward of the granite, there are poor exposures of basic intrusions, in the highroad 200 yards west of Ballalhergy (Sheet 12), and in the gutter adjoining *Booldoholly*, 300 yards farther north.

In the spoil from the East Foxdale Mine at Eairy (Sheet 12), we may observe blocks of olivine-dolerite, derived from a dyke of this type which was encountered in the deeper workings (see p. 515) ; affording another example of the association of olivine-dolerite dykes with metalliferous veins (see p. 488). Though there is no clear exposure of this dyke at the surface, loose weathered fragments occur in the pathway down the steep bank above the southern end of the old dam, 70 yards S.E. of the Chapel, which may indicate an outcrop. No other dyke of this character is known in the Foxdale district.

The broad shelving basin around the headwaters of the Silverburn, BASIN OF between South Barrule and Slieau Eairystane, contains so much drift that THE SILVER the rock exposures are almost confined to the beds of the streams. In BURN. Geaylin ny Cregyn and other of the lower crags on the south side of South Barrule, especially on its eastern shoulder, striped slates with sandy bands are exposed which seem to lie below the level of the Barrule Slate which forms the summit of the ridge. These rocks are highly sheared and the sandy bands are broken up here and there into wisps of crush-conglomerate. These phenomena are also repeated in the low crags on the E. side of Cronk Fedjag 550 yards W.N.W. of Cringle. The prevalent dips in these slopes are towards N.N.W. ; but the next exposures, in the streams farther southward, show the folded rocks with a general inclination to the opposite quarter, where not vertical.

The little side-gullies at *Whallag* and *Reash*, 600 yards E.S.E. of Cringle, are close upon the structural axis of the Island ; and the intensely sheared rocks which they reveal show a high degree of mineral alteration. This is particularly noticeable in the softer slates adjacent to certain massive bands of quartz-veined grit exposed in this locality, the prolongation of those seen on the Carnanes (p. 45). In places the slates with thin sandy layers are converted into true mica-schists with a gneissose fluxion-structure. As these altered rocks are over two miles distant from any known outcrop of the granite we can scarcely assign their metamorphism to the influence of that intrusion (see p. 113). On the other hand, the occurrence of similar phenomena, though usually in a less extreme form, in the axial belt throughout the Island, points to the alteration being in some way connected with the forces which have produced the general structure. The quartz veins associated with these crushed and altered rocks have been implicated in the movements ; and whether from this cause or from their original composition, they are full of yellow mica and fibrous tourmaline. Indications of a normal fault striking N.N.W., of later date than the other movements, are also visible in the above-mentioned gullies.

The more northerly ravine, which contains one of the reservoirs of the Castletown waterworks, has intersected a seam of ochreous earth 1½ feet wide, visible in both banks, 100 yards below the highroad ; it strikes N. 40° W., and appears to represent a decomposed dyke of olivine-dolerite. A broader band of similar material occurs a mile to S.W., on the opposite side of the basin, in a little glen on the north side of Garey Mooar 40 yards below the main road ; and has been opened up by a short adit. The substance, like the decomposed dyke at Maughold Head (p. 556), might be useful as a colouring material.

In all the upper branches of the Silverburn, southward of the belt of grits described in the previous chapter (p. 45), the predominant rock-type appears to be palish grey and blue flaggy striped slate with sandy intercalations, bearing a general resemblance to the Lonan Flags of the sections farther eastward, and indeed perhaps forming part of that division, though left as 'unseparated' on the map. The outcrops, however, are not sufficiently

numerous to justify any general statement. These remarks also apply to the country (in 6-inch Sheet 16) southward up to the edge of the Carboniferous basin. Among the few dykes observed in this area, we may mention a greenstone 10 feet wide, in the bed of *Awin ny Reash* near Grenaby, 250 yards above its junction with the Silverburn; and some minor intrusions of similar material in *Awin Ray* about three-quarters of a mile S. of St. Mark's. The latter stream in this part of its course is for some distance bordered by curious knolls of slate, carved out in post-glacial times through the river having been temporarily diverted from its ancient channel. The wedge of flaggy grit or quartzite in the lower part of this valley has already been described (p. 42).

IN OF
SANTON
ER.

Below Campbell Bridge (p. 167), the Santon valley repeats the features of the Silverburn, and scarcely needs separate description. The spoil-heap of a small trial-shaft near the W. bank, close to the cross-road 400 yards N. of Ballacorris, contains beautiful examples of the cleavage-frilling of slaty bands among sandy flags; and the same structure is well seen in a quarry on the slope 700 yards to S.W. of this spot, near Ballakew. Some interesting facts in regard to the distribution of the boulders of Foxdale granite in this area are given in Chap. IX., pp. 367-70.

The ridge bordering the valley on the eastward shows tracts of grey sandy and bluish slaty flags on Slieau Chiarn (635 feet) and Mount Murray (726 feet), with only an irregular superficial covering of rubble; and similar though smaller outcrops extend thence at intervals southward to the coast. On the western side of Mount Murray narrow 'greenstone' dykes are visible in a slate-quarry 500 yards S.W. of the summit and in other places; and on the eastern side of the hill, in a small excavation on the parish boundary between Braddan and Marown, 300 yards S.W. of *Roschill*, a 9-ft. intrusion of a somewhat different type is exposed.

GGA
ER.

Though at present discharging to the sea in a rocky post-glacial ravine at the edge of the Carboniferous rocks at Cass ny Hawin, the Santon River has probably once reached the coast at Port Soderick, $3\frac{1}{2}$ miles farther north-eastward, through the deep *Crogga Glen*, which is now partly dry and partly occupied by the *Crogga* rivulet, draining the eastern side of Mount Murray. The bed of this stream lies wholly within the Lonan Flags; it reveals a broadish (about 8 ft.) dyke of tough 'dioritic greenstone' in the deep gully 100 to 150 yards south of the railway; and smaller greenstone intrusions are exposed on the eastern margin of the pond below *Crogga Bridge*; at the side of the high-road behind *Crogga House*; and a mile farther north, in a rocky outcrop at the farmstead south of the high-road at Mount Murray.

DLE
ER AND
ACENT
PES

The next stream eastward, known as *Middle River*, which at first runs parallel to *Crogga River* and then turns at right angles northward into a new course to join the Glass near Douglas, shows but few rock-exposures, and these of no great interest. In the upper part of its basin, however, near Ballabunt, a boss of porphyritic igneous material of unusual composition crops out, in a low exposure surrounded by drift-covered cultivated land (for petrographical description see p. 322). The rock is exposed in a disused quarry 300 yards south of *Ballapaddag*, in a field on the western side of an occupation-road. It is seen only in the quarry, and as no indication of its margin is visible in the excavation we have no means of judging whether it is likely to be a dyke or merely a boss. Blocks of this material, presumably transported by glacial agency, are scattered over the steep slope of Richmond Hill on the opposite side of the valley. The road leading to *Speke Farm*, at 200 yards N.W. of the main-road between Richmond Hill and Mount Murray, shows some decomposed ferruginous rubble which may indicate a basic dyke; and blocks of rock like that of Ballabunt are plentiful in the adjacent fences. But the rubble in the roadway is too rotten to show the original character of the rock; and the blocks, like those previously mentioned, may have been glacially transported to this place from Ballabunt.

On the top of the hill south of the cross-roads above Pulrose the soil is full of splinters of slate. The rock is slightly exposed in the adjacent

roads, and must be near the surface in many places in the fields ; but the slaty soil is apparently due to an irregular gravelly cover of re-arranged fragments of the country-rock mixed with a few far-travelled pebbles, constituting a local drift perhaps modified by Late-glacial flood-waters (see p. 371). Similar rubbly deposits are of frequent occurrence on the lower slopes of the slate-massif; and it is well to note that a soil full of sub-angular slaty debris does not necessarily imply the presence of solid rock immediately beneath the surface.

The Lonan Flags are exposed in many places on the slopes of the central valley southward and westward of Douglas, but the sections call for no special remark. The thick bands of quartz-veined grit seen in the vicinity of The Nunnery have already been mentioned (p. 46).

SOUTHERN DIVISION (*Six-Inch Sheets 15 to 19*).

Western Coast.

The cliffs for some distance on both sides of Fleshwick exhibit complex masses of flaggy quartz veined grits and highly-sheared dark striped slates intricately folded together, as described in the previous chapter (p. 44, Fig. 4). The composition of the lower cliff rarely corresponds to that of the precipitous slopes above, for although the rock-bands appear to plunge down almost vertically from the summit they are frequently bent sharply back upon themselves several times before reaching the shore. On the southern side of *Gub ny Traie Ruy*, and again on *Kione Beg* the western boundary of Fleshwick, a crush-conglomerate has been locally produced in the slates in the vicinity of the grits.

CLIFFS NE
FLESHWICK

A small dyke of olivine-dolerite occurs in the cliff north of *The Boe* three-quarters of a mile north of Fleshwick ; another of the same type in a little recess on the east side of Fleshwick, 200 yards south of *Raclay* (Sheet 16) ; a third, accompanying a small vein with traces of copper, on the west side of *Lhoob ny Charran* (Sheet 15), 800 yards west of Fleshwick ; and a fourth on the north side of Bradda Head, at the old mines, exhibiting a main branch striking W. 35° N. across the shore and a flier following the N.—S. course of the lode in the cliff.

These dykes with the examples a little farther north described on p. 150, probably represent the emergence, on the west coast, of the group seen around Castletown Bay on the opposite side of the Island. There are doubtless others concealed in the drift- or talus-covered bays and ghaws of this part of the coast, as the intrusions weather more quickly than the country-rock, and are liable to be hidden in the recesses.

The most southerly and westerly point to which any of the Foxdale elvans have been traced occurs in the upper crags of the cliff on the south-west side of Bradda Hill. Here we find a strip of pale microgranite, 2 feet wide, which is seen at intervals extending thence northward, in disjointed segments, across *Ghaw Doo* ; and, increasing somewhat in thickness, into the lower cliff at *Kione Meanagh* 200 yards west of Fleshwick, where it might readily be mistaken for a crushed quartz-vein. It reappears on the opposite side of the bay in the cliff under *Raclay*, where its sheared and broken condition is excellently displayed. Its course thence up the long steep slopes above the true cliff is indicated only by a few scattered blocks ; until we reach an outcrop of the dyke in the upper range of crags, 500 yards N. of *Raclay*. Although the exposures beyond this point indicate a rapid increase in the thickness of the intrusion, there seems to be no reason to doubt that we are following the same dyke. Its position relative to the outcrop on the shore at *Raclay* appears to show some displacement, possibly due to overthrusting ; or it may be that the intrusion has swerved northward to avoid the adjacent crumpled mass of grit. (See Fig. 4, p. 44.) From the crest of the declivity the segments of the elvan hold an easterly course across the plateau until lost beneath drift at the foot of its eastern slope, 150 yards N.W. of Kirkill farm

At the head of the *Raclay Ghaw* we encounter a 10-ft. dyke of greatly sheared 'greenstone' which is probably intercepted by the elvan, though the section is not sufficiently clear to show the contact. Shreds of a similar dyke are visible in places on the steep seaward slope of *Carnanes* 150 to 250 yards farther southward. A more peculiar dyke, with large crushed felspars, crops out in places among the quartz-veined grits on the southern shoulder of *Carnanes* 300 yards S. of Ballarock. The position of this and the other intrusions mentioned in the foregoing sentences, is indicated in the ground-plan Fig. 4, p. 44. Numerous examples of the ordinary sheared greenstones may be observed on the eastern slopes of Bradda Hill between Fleshwick and Port Erin Bay, but call for no special remark. They are rarer in the cliffs on the opposite side of the Hill.

DDA
D AND
ERIN.

The chief feature in the coast section at Bradda Head is the great N.—S. metalliferous vein so magnificently displayed in the cliffs on both sides of the headland, said by Sir W. W. Smyth to be the finest surface exhibit of its kind in Europe.¹ This vein and the workings on it are described in Chapter XII., pp. 529-32.

The complicated contortions of the grits and slates in the western face of the promontory may be taken as typical of the general structure of this part of the Island. Northerly or N.N.W. dips, at angles generally above 60°, prevail on the coast as far south as Port Erin, after which the dominant tendency of the contorted strata is usually towards the opposite quarter. The change of direction is first seen in a narrow belt of folded flaggy grit or quartzite in the N.E. corner of Port Erin Bay. The dark striped slates on the northern side of this belt of hard rock are reduced in places to the condition of crush-conglomerate, though owing to a later cleavage the structure is not well seen excepting in water-worn slabs. In the middle of the bay the drifts probably extend to low water mark beneath the sandy beach.

FS
H OF
ERIN.

From Port Erin southward to the extremity of the Island the cliffs are composed of striped slates, rather sandy in places, of the characterless 'unseparated' type. Sheared and disjointed dykes of 'greenstone,' including examples both of the dark green and the paler types, are very numerous, scarcely any section being free from them. The largest of these occur in the cliffs around Aldrick (Sheet 15), where, in *Half-way Rocks* on the N. side of the recess, one of the diabases has a thickness varying from 8 to 16 feet; 60 yards farther S. there is a boss or dyke, with a diameter of 18 feet, showing porphyritic structure; and in the cliff adjoining *Clet Aldrick* another example 30 feet wide. Sixty yards S. of the last-mentioned spot, one of the rougher 'diabase' intrusions 8 feet wide seems to have been penetrated by smaller dykes of the paler intermediate type. South of Aldrick the dips again show a northward tendency which is continued across the Sound into the islet of the Calf. In Bay Fine a fracture striking N.N.W., accompanied by fault-breccia and vein-stuff, is seen in the cliff, cutting off several small greenstone dykes; the same fault probably emerges on the opposite coast, a mile distant, at the old mining level at *Rheboeg* in Bay Stacka, and may be the cause of the truncation of the grits of Mull Hill and The Chasms.

In Aldrick a similar fracture strikes nearly N. and S. into the cliff, and is revealed again on the opposite shore 600 yards farther S., at *Carrick Nay* in the Calf Sound; this also has been explored by the miners, who consider it to be identical with the Bradda Lode (p. 532), though the northward prolongation of its strike would lie some distance to the westward of Bradda Head. Other fractures parallel to these are indicated by the narrow water-channels separating the islet of Kitterland from the mainland on the one hand and from *Thousla Rock* and The Calf on the other.

On Kitterland (Sheet 18), which at low tide has an extreme length of 380 yards, thirteen small 'greenstone' dykes were counted, mostly under 3 feet in width, striking E. or E.N.E. with the strata, like the majority of the intrusions on this part of the coast.

¹ "Metallic Mining" in "British Manufacturing Industries," ed., 1876 pp. 304-6.

The Calf of Man.

The Calf (Sheet 18) is composed throughout of slates similar to those of the adjacent mainland. A little basin of shallow drift occurs in the central and southern part of the islet; and in a few other places there are small patches of drift-gravel; but elsewhere the solid rock is at or near the surface. A narrow wedge of thin flaggy grits, in nearly vertical folds, strikes inland from *Fold Point* on The Sound, and may be traced to the top of the slope overlooking Gibbdale Bay, where it is probably broken by a N. and S. fault which appears to traverse the Island to its southern shore at The Puddle. The striped slates which occupy the remainder of the Island are frequently sandy and flaggy, resembling and perhaps being identical with the thin-bedded portion of the Lonan Flags. They frequently possess a tough fibrous structure, like the rocks of Spanish Head. Small dykes of greatly sheared greenstone of various types, frequently in the condition of calc-chlorite-schist, abound in every part, being often in clusters of several individuals running parallel within a few yards of each other; though this appearance may sometimes be simulated by the crenulation of a single dyke. At the N.E. of the Calf these clustered intrusions may be studied at low water on the shore off *Cow Harbour*; on *Kione Beg*; and on both sides of Gibbdale Bay. In its western cliffs they are exposed around the Stack; at *Culbery*, where they are cut off at the foot of the precipice by a thrust-plane; and around Caigher Point. On its south coast they occur on both sides of *Karick*, where the sections are less difficult of access than in most places; and on the E. coast we find them on *Kione Roauyr*; in the adjacent *Ghaw Yarn*; and in the cliff opposite to *The Clets*. They are usually less than 4 feet but occasionally as much as 8 feet or more in width. The largest example observed is 10 to 18 feet wide, and like many of the others, is scarcely recognisable as of igneous origin without (or even with) petrographical examination; it occurs on the foreshore 350 yards N.N.E. of Burrow, and resembles the dyke seen on the opposite shore of The Sound in the cliff near *Creg y Jaghee* on the W. side of Spanish Head, and also that of The Chicken Rock (see p. 304).

The numerous fractures filled with breccia, quartz and other vein-stuff which traverse the slates of The Calf, sometimes, as on the main Island, exhibit slight metalliferous indications. Thus, traces of lead and copper were observed a little to the northward of Caigher Point; Cumming records a small vein of copper pyrites in the vicinity of The Puddle¹; and similar traces are said to have been found in the veins on the N. side of *Fold Point*.

Rock-benches slightly above the reach of the tides, and *ghaws* or deep narrow gashes cutting the cliff-line, in which the sea at its present level is ineffective for erosion, betoken the Raised-Beach period. A ledge of tufa and cemented beach-stuff in a cave at *Bay yn Ow*, 450 yards N.E. of The Stack, may also be referred to this period.

The Chicken Rock is a dangerous low-water reef of striped somewhat sandy slate traversed by greenstone dykes, one large and one small, the larger, 12 to 18 feet wide (p. 304).

Southern and South-eastern Coast.

From the south-western extremity of the Island we will now follow the coast round to the eastward and north-eastward up to the Carboniferous Basin.

The banded fibrous slates of the broad low foreshore bordering Calf Sound are seamed with small dykes of the same character as those on Kitterland. These are especially abundant in *Carrick Noy* to the westward of the fault mentioned above, and in *Baih ny Breechyn*, the next recess eastward. On the intervening headland of Barroo Ned a belt of vertically folded gritty flags, like those of the opposite Calf shore, occupies a portion of the cliff, flanked on both sides with thin-bedded rocks

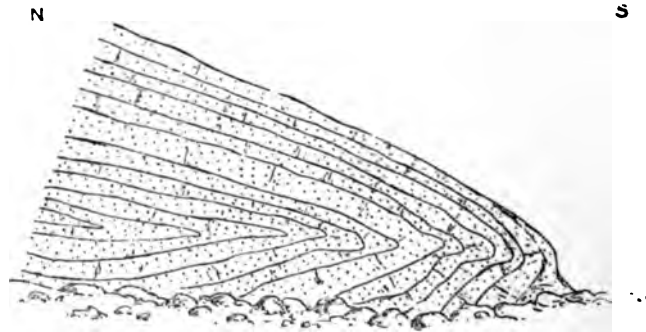
¹ "It runs S. 60° E. mag. and dips S.W. by S at an angle of 70°." "Isle of Man," p. 151.

of the 'unseparated' type. On the W. side of the promontory a small vein shows brilliant blue and green staining from decomposed copper-ore. In *Bailh ny Breechyn* an isolated crag exposed at low water contains a boss of igneous material 20 to 30 feet in diameter, like that of the adjacent dykes, perhaps representing one of the conduits from which the smaller intrusions have drawn their supply. The broad dyke 15 feet wide already mentioned in connection with a similar dyke on 'The Calf' (p. 173) is exposed at the base of the high cliff 100 yards S.E. of this crag; as frequently happens to these intrusions, it is sliced off by a thrust-plane so that only a short segment is visible.

ISH
D.

South of the high broken precipice under *Cronk Moaar*, the dips, after several sharp rolls, come over at the unusually low angle of about 10° towards S.S.E., and the banded slates acquire a peculiarly fibrous structure from the relationship of the planes of shearing to the bedding. The same axis of low dips strikes across the extremity of Spanish Head and reappears in the recess of *Slea ny Bery*, between Spanish Head proper and *Black Head* (Sheet 18). The rock has at one time been quarried both at the top and at the base of the great precipice, the quarryman's old trail down the broken face of the cliff still affording (in 1895-6), a possible but very dangerous means of descent to the shore. This is doubtless the locality referred to by Bishop Wilson,¹ and afterwards by Macculloch,² where "long beams of tough stone, 12 to 15 feet long" were wrought "fit for mantle-trees and strong enough to bear the weight of the highest stack of chimnies." Macculloch states that trials of its flexibility showed that a beam 15 feet long and 2 inches thick was forced 5 inches out of

FIG. 42. *Recumbent fold in flaggy grits in cliff on east side of Perwick Bay, Port St. Mary. Height (maximum); about 60 feet.*



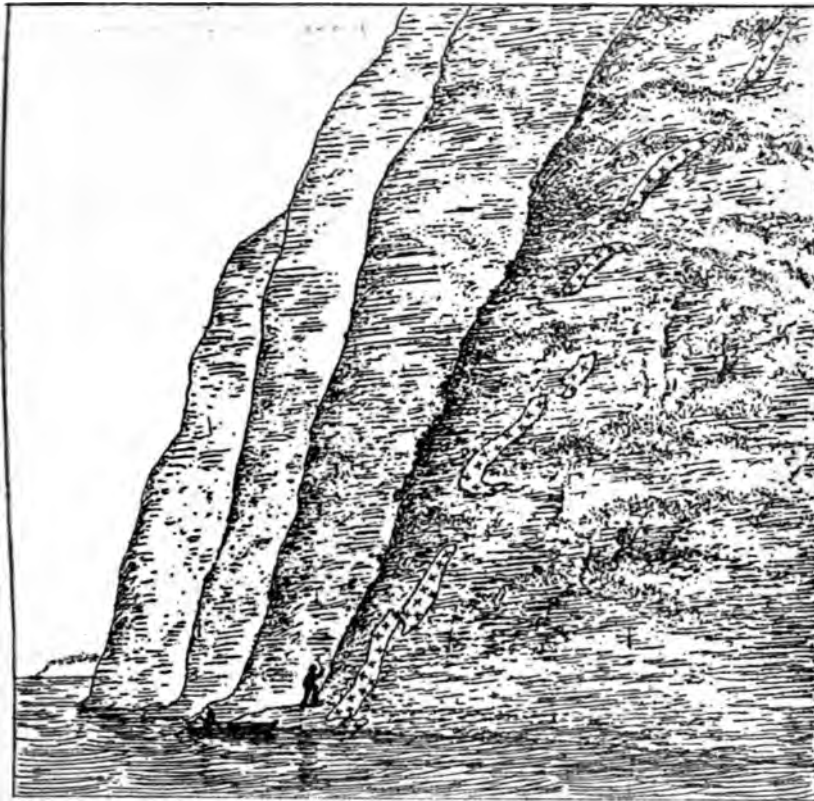
the straight line before it broke.² In Castle Rushen at Castletown, there is a fine floor and also a roof made of these beams laid side by side from wall to wall, 15 feet clear across without support; and it is said the full length of the beams is 23 feet. From the mode of occurrence of similar structure in the slates on the hill-side east of Ballaugh (described on p. 132), it is probable that the low dips on Spanish Head where the fibrous rock is found, mark a synclinal trough. The flaggy grits of *The Charns* and Kioney Ghoggan on the opposite side of Bay Stacka have a similar low dip and appear to overlie the slates; but as stated in the last chapter (p. 43), these strata are probably portions of an overturned fold, in which case their original order has been reversed.

¹ Bishop Wilson's "Description" in Camden's "Britannia" op. cit., 4th ed., p. 392.

² Macculloch, "Western Isles," etc., vol. ii., p. 532.

We find evidence in favour of this reading of the structure, in the presence of small recumbent folds, traceable in the thin sandy layers of the slates in the eastern corner of Bay Stacka north of *The Sugar-loaf* pinnacle; and in the rapidity with which both slates and grits resume their high dips when followed inland from the coast. Similar

FIG. 43. *Diagrammatic sketch of disturbed greenstone dyke traversing Manx Slates in lower part of precipice at Slea ny Bery, Spanish Head.*



recumbent folds are still better seen in the prolongation of these grits north-eastward in Perwick Bay, as shown in the opposite figure (Fig. 42.)

The origin of the curious and much-visited Chasms has been previously discussed (p. 43).

On Spanish Head and in Bay Stacka a few small sheared greenstone intrusions of the ordinary type may be observed. The great cliff on the W. side of *Slea ny Bery* affords an interesting illustration of the manner in which these dykes are torn asunder by later movement, as shown in the above figure (Fig. 43.)

A crag known as *Horse Rock*, visible only at low tide, under the cliff 250 yards S.W. of Kioney Ghoggan, is composed of coarse diabase studded with porphyritic augite, not unlike the diabase of Poortown (p. 304). At its outer edge and along certain planes within the mass, the rock is

greatly sheared and altered by crushing, but in other places it shows scarcely any trace of movement. A small schistose 'greenstone,' 1 foot to 3 feet wide, is seen in the adjacent cliff, but the coarse rock is confined in this locality to the isolated crag.

An interesting dyke of mica-trap of a type uncommon in the Island (p. 302) occurs in the cliff at the head of a little gullet on the N. side of Kioneigh Ghoggan. Its thickness in the coast-section is from 6 to 8 feet, but it seems to be twice this width in the field above, where it forms a low crag. Farther westward, though somewhat difficult to distinguish on account of its schistose structure, we find it in one or two small exposures in the fields between Kioneigh Ghoggan and the Chasms; and at the latter place, both at the top of the cliff and in the sides of the more easterly fissure near the corner of the field-fence overlooking the precipice; and once more, 80 or 100 yards farther west, in the crags on both sides of the slipped ground on which are the remains of a prehistoric stone circle. Where last seen, it is in proximity to a smaller dyke of different composition and direction of strike, but the point of intersection is not revealed. Though the cliffs north-west of Spanish Head lies athwart its westward course, the mica-trap has not there been recognised.

WICK.

In turning into Perwick Bay from westward we find the cliffs composed of quartz-veined grits, with here and there a small schistose dyke, up to 300 yards N. of *Traie Vane*, where these rocks are replaced by smooth banded sericitic slate or phyllite with occasional sandy layers, which occupy the interior of Perwick Bay. An old shaft and level of the Glenschass mine, on a vein striking N.N.W. (see p. 536), are seen at the foot of the cliff west of *Ippney*. The slates are greatly disturbed, sheared and veined with quartz; but their prevalent dip is towards S or S.S.E. at angles rarely exceeding 30°; they are traversed by numerous small greenstone dykes some of which are in the 'calc-chlorite schist' condition. The flaggy quartz-veined grits reappear on the E. side of the bay, in highly contorted bands with crushed schistose slate between them; a seam of coarse breccia, marking a fault or overthrust at their junction with the main mass of the slate, is well exhibited in the isolated *Shag Rock* and on the S.E. side of the little bay W. of *Tortfoggie* (Sheet 16). Accompanying this fracture, in the cliff, is a much decomposed basic dyke or boss 10 to 20 feet wide, with coarse crystals of augite, like that of the Horse Rock (p. 304). The easterly prolongation of this dyke seems at one time to have been exposed in Port St. Mary Bay on the opposite side of the headland, as described by Henslow¹, but is now no longer visible. One hundred and fifty yards farther south, on the foreshore due E. of *Shag Rock*, we reach the fault striking N.E. which brings in the patch of Carboniferous Limestone forming the tip of the headland S. of Port St. Mary (see p. 205).

T ST.
RY BAY.

Crossing into Port St. Mary Bay, to the northward of the fault we find a repetition of the features of the Perwick shore, except that the bands of grit are subordinated to the more argillaceous beds. Dykes are numerous and mostly in the schistose condition, but two distinct types seem to be represented; the one crushing down to a smooth pale greenish grey or slightly ferruginous schist which is softer than the country rock, while the other forms tough darker gritty-looking bands thicker and more resistant than the surrounding strata. A good example of the latter type, 8 to 10 feet thick, occurs in the low ridge jutting out from the cliff immediately to the N. of the Cliff Hotel.

Ganseigh Point and *Carthure Rocks* contain much flaggy grit, folded among striped somewhat sandy slates, along with several small dykes, two of which on the E. side of *Chapel Bay* seem to belong to the mica-trap group (p. 303), while the others are of the types above described. Between *Ganseigh* and *Rhenwyllan*, the low rocky foreshore reveals a broad belt of grit, probably

¹ Trans. Geol. Soc., vol. v., pp. 491-2. See also B. Hobson; *Quart. Journ. Geol. Soc.*, vol. xlvii., p. 434. The loose block referred to by Mr. Hobson on the inner side of Port St. Mary New Pier is, however, probably a transported boulder.

the continuation of that which forms the craggy ground on *Cronk Skibbylt* to the westward of Port St. Mary; and similar rocks are exposed in the gutter of the little stream both above and below the corn-mill at Rhenwyllan. For over half a mile to the east of this place the broad sandy foreshore of Bay ny Carrickey is probably everywhere underlain by drift or alluvium; but in the Black Rocks opposite Kentraugh the slates again crop out and occupy the whole breadth of the tidal platform. The low-water reef of *Cronnag* is composed of folds of pale grit or quartzite, like that near Rhenwyllan; while the higher portion of the shore contains sheared banded slates, with the dominant planes dipping towards S.S.E. Small Pre-Carboniferous dykes are abundant, especially in the eastern part of the exposure, some of which are in the schistose condition while others are of the less altered type. We also find three examples of the Post-Carboniferous olivine-dolerites; one near the western end of the rocks, 350 yards east of the mouth of Colby River; and the second and third, respectively 340 and 420 yards farther east (for other details see Table on p. 331). Opposite to the cottages at *Grenea* (six-inch Sheet 16), the boundary fault of the Carboniferous rocks, after its submarine course across the bay from Port St. Mary, again crosses the shore, and brings in the Carboniferous Limestones. The slates may be traced with some difficulty to within a few feet of the fault, but the actual line is concealed, partly by beach-material and seaweed, and partly by patches of boulder-clay which towards high-water mark have not yet been entirely removed from the Pre-glacial rock-platform.

BAY NY
CARRICKE

Leaving the details of the Carboniferous rocks for description in a later chapter, we pass now to Langness, on the eastern edge of the Carboniferous basin, 4 miles distant, where the Manx Slates again emerge.

The exceptional interest of the sections on Langness has long been known to geologists through the work of Cumming and other observers. The shores of the promontory present so much complicated detail that it was found impossible to render the facts on the 6-inch map, and the 25-inch scale was therefore adopted for this part of the coast. [6-inch, Sheets 16 and 19; 25-inch, Sheets 16 (of 6-inch, 16) and 4 (of 19).] The instructive phenomena accompanying the overlap of the Carboniferous Conglomerate upon the Manx Slates are described in the chapter following (see p. 195). The Langness sections show clearly that the slates, with their greenstone dykes, had acquired their pressure-structures long anterior to the earliest stages of the Carboniferous; and that the relative resistance of their constituent beds to the attack of the waves on the Carboniferous shore was not different from what it is on the present shore. (See Figs. 50, 51, pp. 191-3.)

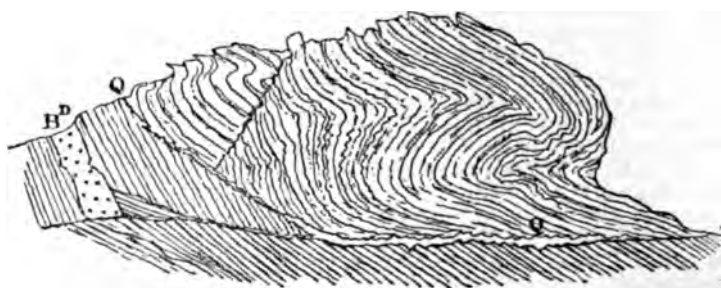
LANGNESS

On the western side of Langness the most northerly point at which the slates are seen is in a low bank 50 yards north of Langness farmstead, where they are brought up against the Carboniferous Basement Conglomerate by a small fault. They consist of thinly-bedded rather flaggy slates, dipping S.S.E. at about 45°, stained to the purplish tint which they usually show when in contact with the red Conglomerate. They are again brought in by another small fault in the low section near the *Langness Copper Mine* 500 yards farther south (see p. 538); and are continuous thence southward, for 350 yards, in the cliff and the upper part of the foreshore, to *The Arches*, where the unconformable position of the Conglomerate upon them is magnificently displayed (see Fig. 49, p. 190). They are traversed in this interval by several small Pre-Carboniferous dykes; and by an intrusion of less usual character, probably connected with the Carboniferous Volcanic series, which after intersecting the slates in the low cliff is seen also to penetrate the Conglomerate on the shore a few yards north of *The Arches* (see p. 325). In the rough ground 70 yards inland from the cliff, 200 yards south of the mine buildings, there is a small exposure of an olivine-dolerite dyke in the slates, probably one of the group which traverses the Carboniferous Conglomerate on the shore below the mine (p. 195).

South of The Arches for 400 yards, the sections are composed entirely of the Conglomerate; but at *Port Bravag*, under the shelter of Langness Point, the stained slates reappear from beneath it, and the unconformable junction may be followed thence across the narrow neck of land to the outer shore at *Dreswick Harbour*, the Carboniferous rocks thus isolating the little peninsula of slate which forms Langness Point and the low-water reef of *Skerranes* (Sheet 19). In this tract the slates are traversed by a plexus of dykes and bosses of 'greenstone,' mostly of the 'camptonite' type (see p. 300), striking generally E.N.E. with the stratification; and the slates are also gashed by a set of north and south fractures, worn into 'gulleys' by the sea, and filled with water at high tide. In at least two instances these fracture-lines cut off or displace the greenstone dykes; but as the intrusions are everywhere irregular, the amount of faulting cannot be deduced. One of the gashes is occupied by an olivine-dolerite intrusion, 1 to 2 feet wide, accompanied along part of its course by a narrow vein of copper-pyrites which has been tested by a mining shaft and cross-cut.

FIG. 44. *Section on north side of Horse Gullet, Langness, showing thrust-planes and accompanying plication of thinly-bedded sandy slates.*

Height about 12 feet.



Bp. Greenstone dyke, 2 feet thick.

T. Thrust-plane, with Q, quartz-veins.

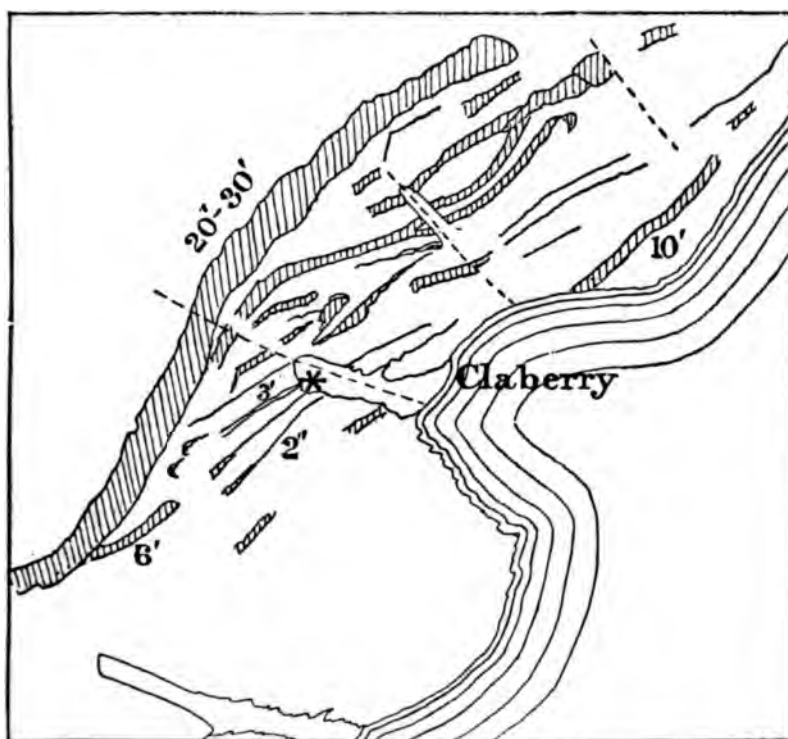
On the eastern side of *Dreswick Harbour*, under the Lighthouse, the sections again show the emergence of the slates from beneath the Carboniferous Conglomerate (for descriptions see p. 191, Figs. 50, 51). Thence north-eastward, the whole of the outer coast of Langness is composed of the slate rocks, varying in their lithological characters but not perhaps to a greater extent than we find in the southern portion of the *Lonan Flags* bordering the Carboniferous basin farther north, to which as a whole they bear much resemblance; and it is questionable whether these Langness rocks should not have been mapped as part of that division instead of being left in the 'unseparated' class. But as strata of similar type also occur to the westward, in *The Calf* and the coast adjacent to it, closely associated with and inseparable from rocks devoid of the characteristics of the *Lonan Flags*, it was not thought advisable, in the present state of our knowledge, to carry that division south of the Carboniferous basin.

From *Dreswick Point* to *Tarrastack Rock*, dark striped slates predominate; farther north the proportion of sandy material increases, and flaggy layers of grit are sometimes numerous; north of *Martha Gullet* (northern edge of Sheet 19), and especially in the vicinity of *Horse Gullet* and *Scottens*, arenaceous strata in the form of thin flaggy grits or imperfect quartzites

with argillaceous partings are in the ascendancy; while beyond *Claberry* there is a change in the reverse order, the rocks becoming more thinly bedded and more slaty again in going northward to St. Michael's Island. The prevalent dip throughout is towards S. or S.S.E., though with local variations tending frequently to swing the direction some degrees W. of S. The angle is usually high, ranging between 50° and 70° . Lines of crushing

FIG. 45. *Ground-plan in vicinity of Claberry Gullet, Langness, showing plexus of greenstone dykes in contorted sandy slates.*

Scale, 25 inches = one mile.



The numbers indicate the thickness of the dykes in feet:

* shows position of section given in Fig. 46.

and faulting, apparently often marking small overthrusts, are of constant occurrence, and are generally accompanied by more or less vein-quartz. The general structure is illustrated in the opposite section (Fig. 44), in which, however, the folds are less strongly isoclinal than usual.

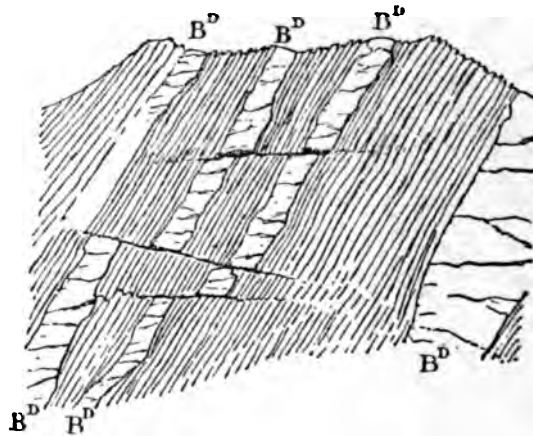
In the thinly-bedded sandy slates, 'worm-markings' are in places abundant; they may be best studied in weathered crags a little above high-water mark in the cliffs on both sides of *Martha Gullet*; on the northern side of *Horse Gullet*; and in the vicinity of *Gullet Buigh*. The indications of shearing are not so strong as is usual in the Manx Slates; and the strain-slip cleavage is often only visible where brought out by

weathering. The direction of this cleavage is approximately that of the bedding, but often at a different degree of inclination; in which case the intersection of the two sets of planes at the edge of the flags when weathered, gives the 'corded' structure described in the last chapter (see p. 73, Fig. 17).

In no part of the Island are the basic igneous intrusions more numerous and more diverse than on Langness, though the granitic elvans are absent. The majority belong to the camptonite group of greenstones (see petrographical description and other details in Chap. VIII, pp. 300-4), and these, along with the diabases and diorites, are of Pre-Carboniferous age; but there are, besides, many of the Post-Carboniferous olivine-dolerites, as well as the supposed Carboniferous dyke mentioned on p. 177. The Pre-Carboniferous intrusions are, on the whole, much less crushed and altered than in the area to the westward of the Carboniferous basin; indeed, between

FIG. 46. *Cliff-section on south side of Claberry Gullet, Langness, showing small greenstone dykes (B^p) cut and shifted in segments along horizontal planes of dislocation.*

Height about 35 feet.



Langness and Douglas Head these dykes are fresher and less crushed than in any other part of the Island, probably because the compressive forces acted with less intensity on this flank than in the central zone of the massif. The smaller dykes usually strike about E.N.E. with the bedding, but the larger bosses are less influenced by the stratification, and frequently have N.E. or N.N.E. courses.

Starting again from the southern extremity of the peninsula, we find everywhere between Dreswick Point and *Spire Gullet* greenstone intrusions of small size striking obliquely across the craggy foreshore. To the northward of *Spire Gullet* they are of less frequent occurrence until we pass *Creg Custane*, but are present in numbers again in the vicinity of *Martha Gullet* and between *Bailie* and *Horse Gullets*. In the craggy ground at the top of the cliff between *The Cooll* and *Scottean* (Sheet 16) the first of the broader dioritic dykes, 10 to 20 feet wide, is encountered, arranged as usual in interrupted lenticular segments. In a similar position north of *Gullet Buigh* another or possibly the continuation of the same mass may be traced northward for nearly 200 yards. To the seaward of it there is a plexus of smaller disjointed intrusions, as shown in the foregoing plan

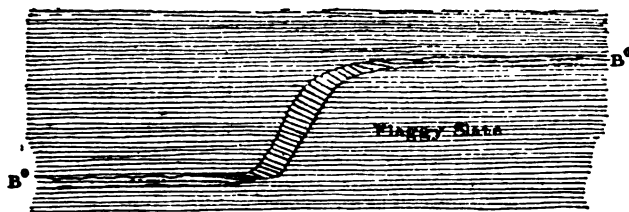
copied from the 25-inch map (Fig. 45); and the manner in which they are broken and displaced vertically as well as horizontally is seen at the same place, in the section exposed in the walls of *Claberry Gullet* (Fig. 46).

Another boss or segment of diorite crops up in the field opposite *Gullet Creagh Moainee*, 70 or 80 yards due N. of the last exposure; and again farther north, 50 yards E. of the S. end of the causeway to St. Michael's Island, where it is seen in a crag above high-water mark and also on the foreshore. This intrusion has been described by Mr. Hobson.¹ Detached masses of similar material also occur on the west shore of the above-mentioned Island, N. of the causeway.

The following plan of a small dyke exposed near high water mark on the shore 50 yards S. of *Gullet Creagh Moainee* illustrates the extent of the deformation of the rocks through shearing even in this comparatively little disturbed area, and the difference in its effect according to the position of the dyke in regard to the direction of movement.

FIG. 47. *Ground-plan on shore south of Gullet Creagh Moainee, Langness, showing effect of shearing upon thickness of small greenstone dyke.*

Area 35 feet by 15 feet.



Where the dyke (B^c) lies between the bedding planes of the flaggy slate, its thickness is from 2 to 4 inches; where it cuts across the bedding, it expands to 12 inches and shows oblique cleavage.

On *Hango Broogh*, 200 yards farther N. (not to be confounded with the better known hillock of drift of the same name opposite the College at Castletown), the chief dyke is a porphyritic camptonite, about 12 feet wide, which is described on p. 303. Segments of the same or a similar dyke are exposed on the opposite foreshore of St. Michael's Island, along with many of smaller dimensions.

The most noteworthy intrusion on St. Michael's Island is a mass of **ST. MICHAEL'S ISLAND.** green schistose rock, 30 feet wide, apparently a highly sheared diabase different in structure from any other of the Langness dykes, which strikes N.N.W. from near low-water to some distance above high-water mark S.S.E. of the roofless ancient Chapel. On account of its slaty fracture, this intrusion might easily be passed over without recognition; it has been quarried, and largely used in the walls of the old Fort (dating from about 1650²) where it has resisted the weather remarkably well. A small dyke of the paler 'camptonite' type, with the usual E.N.E. strike, can be traced up to the flank of the larger mass and reappears in the same line on the opposite side; but although it is most probable that the smaller dyke is continuous across the diabase, the exposure at this point is unfortunately not sufficiently clear to place the matter beyond doubt. The more highly altered and schistose condition of the larger intrusion,

¹ Quart. Journ. Geol. Soc., vol. xlvii., p. 447.

² See Cumming, "Isle of Man," p. 94.

though to some extent explicable as the result of its abnormal strike athwart the cleavage, is further evidence for its greater antiquity.

The olivine-dolerite dykes of Langness preserve the accustomed N.W. or W.N.W. trend, whether they traverse slate, conglomerate, or limestone. An example 2 feet wide occurs on the N. side of Dreswick Point, striking into the cliff near the S.E. corner of the Lighthouse yard; another, still smaller, on the N. side of *Spire Gullet*; a group of branching and interlacing strings, intersecting a 'greenstone,' between *The Goayr* and *Creg Custane*, 220 yards farther N.; a similar but broader group, in the recess on the S. side of Martha Gullet, with a flier in the Gullet itself; after which there is an interval of three-quarters of a mile before we reach the next, on the S. side of the inlet isolating St. Michael's Island, wherein a thin branching dyke may be seen struggling in a sinuous course across the S.W. side of *Hango Broogh* and the shore to the westward, reappearing on the beach at the N. end of the causeway on St. Michael's Island.

On the shore of Derby Haven west of St. Michael's Island the slates with their associated small intrusions, though much obscured by seaweed and beach-material, may be traced up to the edge of the Carboniferous rocks which occupy the interior of the Haven. In the middle of the inlet, 50 yards south of the Breakwater Lighthouse, a little patch of the stained slates unconformably overlain by the Carboniferous Conglomerate is brought up by a small fault just above the level of the lowest tides. A dyke of olivine-dolerite accompanies the fault.

South-eastern Coast, north of the Carboniferous Rocks.

The Carboniferous rocks end off against an east and west fault (see p. 199) which brings up the slates on the coast at Cass ny Hawin (eastern edge of Sheet 16). Besides the boundary fault, there is at this point, as Cumming observed,¹ a cross-fracture striking N.N.E., which shows as a broken fold and crush-belt in the Limestone, but makes a more definite fault in the Slates, bringing down stained rocks on the eastern side against unstained beds on the western. As already remarked, the slates north of this place, though recognized as forming part of the Lonan Flags, do not greatly differ from those of Langness, being chiefly thinly-bedded strongly-striped pale grey and blue flaggy rocks, greatly crumpled and folded, with a prevalent dip towards S.S.E. at high angles. In places they contain hard concretionary nodules, sometimes pyritous, sometimes with cone-in-cone structure in their outer portion. Pseudo-ripple-marking (see Fig. 18, p. 74), pseudo-cross-bedding and other deformation structures are in places beautifully developed. Small sheared disjointed dykes, chiefly of the 'camptonite' type, are as abundant as on Langness, and present the same general characters.

NY
IN.

The sections differ from those of Langness, however, in the presence, in places, of massive bands of coarse pebbly grit and quartzite of peculiar character. Conspicuous among these is a bed of quartz-veined quartzite, 15 to 20 feet thick, which abuts against the boundary fault on the shore at dead low water at Cass ny Hawin, and strikes thence N.N.E. into the cliff on the S. side of Cass ny Hawin Head (Sheet 17). Like the dykes, this band is broken off into disjointed segments which are arranged *en echelon*, being apparently shifted bit by bit northward by faults or thrusts; and it also often simulates an intrusion by breaking across the bedding planes of the softer strata in contact with it, as elsewhere described (p. 46). It is here and there accompanied for a short distance by small dykes which have found vent along its margin.

This quartzite may be traced in the cliff for about 200 yards and is then lost; but reappears 300 yards farther N., on the S. shore of the inlet of Port Soldrick (not to be confounded with Port Soderick, $3\frac{1}{2}$ miles distant).

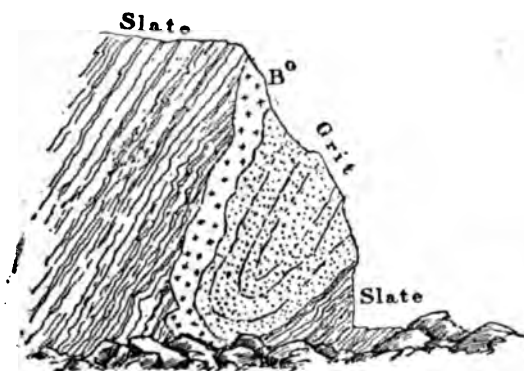
¹ "Isle of Man," p. 109

It seems then to be shifted southward to near low-water on the opposite side of the inlet ; whence its segments may be traced, as before, for over 300 yards, until cut off in the cliff by another fault and lost, the line of fracture being occupied by an olivine-dolerite dyke striking N.W.

In the last-mentioned cliff-section there is evidence that the band is sharply folded, and that its apparent thickness is thereby increased, as shown in the following figure ; a greenstone dyke (B) has been intruded near the junction of the grit with the slate, apparently after the folding took place.

FIG. 48. *Diagram of cliff-section on the eastern side of the second recess east of Port Soldrick. Explanation in text.*

Height about 50 feet.



The massive quartzite of the isolated outcrop in the N.W. of the Island near Skerestal (Sheet 6), described on a previous page (p. 137), bears much resemblance to this band.

On the shore near low-water mark south of Cass ny Hawin Head, to the seaward of the quartzite, we reach the most southerly exposure of the pebbly grits of Santon Head whose main development farther northward was discussed in the foregoing chapter (pp. 46-7). Off the headland, these grits disappear and are not again seen above low-water mark for nearly $1\frac{1}{2}$ miles. Between Port Soldrick and Port Grenaugh and thence to *Traie ny Sloat* thin-bedded sandy slates and flags prevail in the cliff, with harder thicker greenish-grey flags of the more typical Lonan type at low-water and in places reaching the cliff-line. This part of the Island is so thoroughly riddled with the greenstone dykes that six or eight of these intrusions may frequently be counted between high and low water on the broader tracts of foreshore. They fall into two ill-defined classes, possibly of somewhat different age ; one group consisting of fine-textured somewhat pale greenish-grey rocks of the camptonite type, probably the older ; and the other, of dark newer-looking diabase, weathering with a roughish surface ; but minor differences and intermediate variations are common (see p. 298). Instances of small dykes intersecting others of previous consolidation may be observed in several places, e.g., in the cliff 600 yards west of Port Grenaugh.

This part of the coast is also traversed by a group of the olivine-dolerite intrusions ; of which the most southerly is that occupying the fault referred to above ; while four others occur between that spot and Port Grenaugh ; and two more between Port Grenaugh and *Purt Veg* (see list, p. 330), of which the more westerly accompanies a line of fault striking N. 20 W. into the cliff on the east side of *Traie ny Sloat*, 700 yards east of Port Grenaugh.

ST WEST Thick-bedded fine-grained splintery flags make their appearance in the
ST. ANN'S cliff on the eastern side of the last-mentioned fault, and are associated with
AD. bands of pebbly grit like those of Cass-ny-Hawin Head. These pebbly bands are well seen in *Purt Veg*, where they extend inland for at least 200 yards, being exposed in the craggy ground on the S. side of Mary Voar farm. They are lost in the projection of the coast to the E. of *Purt Veg*, which is composed of the thick splintery flags in wide folds; but reappear in the recess on the west side of St. Ann's (Santon) Head, and are continuous thence eastward for 200 to 250 yards until they 'nose out' in the cliff on the eastern flank of the headland through the pitching of the folds, as described on p. 47, Fig. 5.

TH OF The northerly trend of the coast beyond St. Ann's Head carries us
ANN'S gradually out of the region of the thick-bedded sandy flags, which about
AD. half a mile N. of the headland begin to alternate with more thinly bedded rocks with a larger proportion of argillaceous material, like those of Port Grenagh. At Pistol Castle and thence to Staiden this latter type predominates; but is replaced by thicker flags again at the next headland and in the cliffs beyond, up to the southern margin of Port Soderick (Sheet 13: see p. 155).

Though not again well seen on the coast, the coarse grit and quartzite crop cut in low broken ridges, probably the crests of folds, at Ballacregga, a quarter of a mile inland from Staiden.

The character of the folding in these sections suggests that the synclinal trough of Clay Head and Douglas Head (see pp. 151-3) is prolonged under the sea and skirts this part of the coast not far below low-water, so that the more salient points like *Gob Lhiack* (S. of Port Soderick) and St. Ann's Head come nearly into the bend of the trough.

To this cause we may perhaps assign the deflection noticeable in the greenstone dykes between *Purt Veg* and Port Soderick which rarely pursue the customary E.N.E. strike, but are usually coursed E. 10° to 30° S. We have already noticed a similar deflection in the dykes of Clay Head and parts of Douglas Head, and have discussed the probability that the change of direction is in some way connected with the synclinal axis.

Certain of the thicker diabases in this area, of fresher aspect than the rest, may be of newer date than the majority of the greenstones.

Of the numerous dykes of this coast it will suffice to enumerate the following, which are much above the average in thickness:—a diabase of 9 feet, on the eastern side of *Purt Veg*; a similar dyke of 10 to 15 feet, in the cliff 300 yards N. of Pistol Castle; and another of 10 feet or more in a low-water crag at Staiden. The olivine-dolerites are represented by a small example in the cliff 350 yards N. of Staiden; the elvans seem to be absent.

Interior of the Southern Division.

An account of the stratified rocks of the interior of the peninsula between Port Erin and Port St. Mary (Sheets 15 and 18) has been given in the previous chapter (p. 42-3; see also Fig. 20, p. 76); and also of those of the high ground N.E. of Fleshwick (Sheet 16: p. 44, and Fig. 4). Of the igneous rocks of this area not already noticed, the only one requiring individual mention is a small band of somewhat peculiar character, obscurely exposed on the southern slope of Mull Hill a few yards N.W. of the high-road at the edge of the moorland at Cregneish, and again on the hillside E.N.E., of *The Chasms*, which may possibly be of volcanic origin (see p. 324).

BY The upper waters of the Colby River (Sheets 12 and 16) cross the strike
IN BASIN. of the Carnanes quartz-veined grit bands (p. 43), but these rocks are not so well exposed in the stream as on the steep ridge of *Slieu Eairystane* to the eastward of it (p. 45). The grits are again slightly exposed on the lower cultivated ground to the westward of the river, near the houses 400 to 500 yards S. of Lhingague, and at Cronkedooney (Sheet 16). In the remainder of the stream-course, down to Colby where the solid rocks are lost

beneath drift and alluvium, we find alternations of thinly-bedded slaty and sandy flags, like those of Langness; and similar strata are seen in the scanty exposures which occur amid the cultivated slopes extending thence eastward to the margin of the Carboniferous rocks and the valley of the Silverburn (see p. 169). The dominant dip of the stratification throughout this district is towards S.S.E., but sharp isoclinal folding is often visible.

A dyke of 'greenstone' 10 feet wide occurs in the main stream at the weir above the mill at Colby, and a quartz-vein adjacent to it has yielded indications of lead-ore. A similar intrusion, 600 yards W.S.W. of this, in the bed of the *Bellabey* tributary 40 yards above *Ballasherlocke*, is probably the prolongation of the same dyke. A smaller example is exposed in the channel of the little feeder flowing S.W. from Greyney Moor, 350 yards above its junction with the main stream.

An olivine-dolerite dyke, about 10 feet wide, in which the olivine crystals are unusually well preserved, crosses the bed of the Colby due W. of Ballacannell, not far from its source (N. edge of Sheet 16). Another of these supposed Tertiary intrusions is revealed about 30 yards below the bridge at the Corn Mill in Colby village; and again on the W. side of *Bellabey Glen* nearly opposite to *Ballasherlocke* where a mining level has been driven into the bank. In the Ballacorkish lead-mine, 500 yards farther west, from which a considerable quantity of lead-ore has been raised, a similar dyke accompanies the metalliferous lode and has been penetrated for some distance in the galleries of the mine. The lode has a general N.-S. course, but is displaced by E.-W. faults or "slides." (See further details, pp. 532-4.)

In the same district the relics of unsuccessful mines may be seen 250 yards north of *Ballasherlocke*, and again half a mile east of Colby, 300 yards north of the main road (p. 535).

South-eastern Area.

To the north-eastward of the Carboniferous basin (Sheet 17), the country is occupied by the thinly-bedded slaty and sandy Lonan Flags excepting in the vicinity of the coast, where the grits and quartzites already described are locally developed. The lower ground is usually heavily encumbered with drift; but on the rise between the valley of the Santon Burn and Glen Grenaugh there is a tract in which rock, more or less weathered, is generally near the surface; and similar conditions recur in the vicinity of the dry Crogga Glen (p. 170).

A boss of igneous material different from any of the other intrusions of OATLAND GRANITITE the Island crops out in the northern part of this area, near the farm of Oatland (Sheet 17 and extending into Sheet 13). The chief exposures occur in a series of low crags, which are quarried for road-metal by shallow excavations in a field 300 yards west of the farmhouse. The rock at this place is a palish grey close-grained granite (see p. 321), but this material is fringed on the westward, northward and eastward by a narrow rim of dark green diabase full of augite crystals. This diabase crops out in the same field, in the crags near the N.W. fence; in the next field north-eastward, 60 yards from the fence; in front of the house and in the farmyard at Oatland; in the field on the S.E. side of that containing the granite quarries; and in the field adjoining the last-mentioned on the west. The actual contact of the granite with the basic rock was not visible in 1896-7; but that they are conterminous is beyond doubt, since in its northerly outcrop close to the N.E. fence of the quarried field the granite is full of angular or partially rounded fragments of the basic rock, while the latter in Oatland farmyard is veined with thin strings of the granite. These facts also indicate that the acid rock is of later consolidation than the diabase. Further particulars respecting the relationship of these rocks, along with an account of their petrographical structures, are given in Chapter VIII., pp. 320-2.

The northern and southern margins of this complex intrusion are hidden by drift ; but on the east, in front of Oatland farm-house, baked splintery flags are seen close to the contact, and on the western side there is, in a small quarry, a still better exposure of similar flags, traversed by a basic dyke 2 feet wide. Altered splintery flags are also revealed in a quarry by the side of the road, 200 yards due south of Oatland. The total length of the intrusive boss from N.E. to S.W. is probably about 900 yards, and its width from N.W. to S.E., 300 yards.

It is possible that a small boss of diorite may exist immediately beneath the surface in a field (on which *Wells* is engraved on six-inch Sheet 17) nearly half a mile west of Santon Church, or 250 yards W.N.W. of Ballacrine farmstead, as the soil near the N.W. fence of the field is full of angular fragments of this material. A thickish greenstone dyke, perhaps a continuation of that in the bed of *Crogga River* previously described (p. 170), crops out on the steep hillside, 60 yards north of the railway, at the S.W. entrance to *Crogga Glen* (Sheet 17). Smaller dykes of similar character occur in the railway cuttings respectively 600 yards and half a mile east of Santon Station ; but considering the manner in which the adjacent coast-line is permeated with dyke-material, it is remarkable how few of the intrusions are visible in the inland exposures. The more rapid decomposition of the igneous rock, together with the difficulty in distinguishing the dykes from the flags, especially in small outcrops, may perhaps be the reason for the discrepancy.

CHAPTER V.

THE CARBONIFEROUS ROCKS OF THE SOUTHERN DISTRICT.

Historical and General.

The presence of the small tract of limestone in the south of the Island has received notice in most of the old topographical descriptions, on account of its economic importance in a country so generally devoid of calcareous rocks. The quarries in this rock have not only been the chief source of lime in the Island, but have also furnished its best building stone. The ancient and well-preserved Castle Rushen at Castletown, dating back at least to the 13th century, is built of this local limestone.

Of the early geological writers, Woods described the Carboniferous rocks of the south as "transition limestone"; Berger classed them as "Floetz Rocks," and observed with regard to the fossils that Parkinson had noticed "that the whole much resemble those found in Westmorland, Cumberland, Durham, and, as far as he can judge, those of Kilkenny." Macculloch discussed at considerable length the relations existing between the stratified and unstratified portions of the limestone at Poolvash and elsewhere, and noticed the unconformability at the base of the conglomerate associated with the limestone on Langness. In the nomenclature of the period, he classed the slates as "Primary," and the limestone and associated strata as "Secondary." Henslow gave a more generally accurate account of the extent and stratigraphical relations of these deposits, and was the first to recognise the volcanic character of the breccias overlying the limestone on the coast between Scarlet and Poolvash.

When the term "Carboniferous" was introduced for the equivalent rocks of the mainland, the Manx limestones were relegated to this system without further question; and were thus shown on the map published by Conybeare and Phillips in 1822.¹ Indeed, this classification had been adopted some years previously by William Smith in his manuscript geological map of England and Wales,² and under the title of "Derbyshire Limestone," in his published map of 1815.

Towards the middle of the century our knowledge of these

¹ Frontispiece to "Outlines of the Geology of England and Wales." The map bears the date 1821, but the title page of the volume is dated 1822.

² See Prof. J. W. Judd on "William Smith's Manuscript Maps." *Geol. Mag.*, dec. iv., vol. iv. (1897), p. 446.

rocks was greatly extended by the Rev. J. G. Cumming, whose painstaking investigations of the Limestone Series and its fauna supplied a wealth of careful and accurate detail upon which we shall draw extensively in the subsequent pages. As mentioned in a previous chapter (p. 18), this author divided the series into Old Red Sandstone and Conglomerate; Lower or Castletown Limestone; Upper or Poolvash Limestone; and Posidonia Schist or Poolvash Black Marble. Owing to the extremely limited superficial extent of the two latter of these divisions and to their peculiarly complicated outcrops, it has not been found practicable to show them separately from the Lower Limestone on the Survey Map, but they will be treated independently in the descriptions which follow.

The contributions to our knowledge of the Manx Carboniferous Limestone since Cumming wrote have been few and unimportant; they consist principally of incidental references to Manx fossils in works dealing with the palæontology of the Carboniferous System (see Bibliographical Appendix, pp. 590-5). Our knowledge of the Carboniferous Volcanic rocks of Scarlet has, however, meanwhile been largely augmented by the labours of Messrs. Horne, Ward and Hobson, and Sir Arch. Geikie (see pp. 228-33); and in recent years the surmises of Cumming and others (see p. 280) that Carboniferous rocks might exist beneath the drift-plain at the northern extremity of the Island, have been verified by deep borings carried out by Messrs. Craine Bros. of Liverpool. These borings have, as yet, been too few in number to make clear the full extent and composition of the Carboniferous strata in this area, but are sufficient to prove their greater thickness and diversity than in any other part of the Island. We owe to Prof. W. Boyd Dawkins and Mr. J. Todd the first published information regarding these borings (see pp. 280-95).

Like the southern Limestones the little strip of Red Sandstone and Conglomerate on the western coast north of Peel has received notice in all the early topographical and geological accounts of the Island, as being the only "freestone" found therein. It was classed by Berger, Macculloch and Henslow with the Conglomerate which underlies the Carboniferous Limestone at Langness, but was shown as 'New Red Sandstone' in the map of Conybeare and Phillips of 1822 (see p. 264). Cumming and the later writers on the subject were unanimous in considering it to be older than the Carboniferous Limestone of the southern basin, until 1894, when Prof. W. Boyd Dawkins in publishing a more detailed account of the deposit than had hitherto been attempted, claimed it to be of Permian age (see pp. 266-7). While the insufficiency of the stratigraphical evidence leaves this question of age fairly open to debate, it has seemed to the present writer, as will subsequently be shown, that the weight of probability is still in favour of the older and long accepted view; and the rocks have therefore been classified on the map as Basement Beds of the Carboniferous.

In the following pages, the rocks of the three above-mentioned areas, being both lithologically and geographically distinct, will be separately described, in the following order:—

1. The Conglomerate, Limestones, and Volcanic Rocks of the Southern Basin. - (Chap. V.)
2. The Peel Sandstones. (Chap. VI.)
3. The strata underlying the Drift of the Northern Plain (Chap. VII.)

THE CARBONIFEROUS BASIN OF THE SOUTH OF THE ISLAND.

From the variety of its phenomena and their magnificent display in the coast-sections, this small tract of between 7 and 8 square miles in extent is of exceptional geological interest. It stretches from Cass-ny-Hawin (the mouth of the Santon River) on the east, to Bay-ny-Carrickey on the west, a distance of $4\frac{1}{2}$ miles; and from Langness Point on the south, to Athol Bridge (where the Peel and Castletown highroad crosses the Silverburn) on the north, a distance of 4 miles, Castletown the ancient capital of the Island lying nearly in the middle of the basin. In outline, the basin is somewhat oblong, with the longer diameter running N.E. to S.W., or parallel to the hilly central axis of the Island. The limestones of which it is principally composed are fringed on the north-east and south-east sides by the basal conglomerate; are cut off by a fault on the north-west; and bounded by the overlying volcanic rocks and by the sea on the south. Its highest strata lie adjacent to the coast about a mile to the westward of Castletown, and are surrounded by the lower divisions on all sides except the south, where they pass beneath the sea.

In the interior the limestones occupy a low-lying undulating tract usually covered thickly with drift or alluvium, their exposures being almost limited to the valleys of the Silverburn and one of its tributaries north of Ballasalla, and to certain large quarries west of that village. Under these conditions, the exact inland boundaries can be fixed at only a few points, and must be drawn more or less conjecturally across the intervening spaces; and as small faults are numerous in the district, the dotted boundary shown on the map can be only approximately correct.

Basing our classification upon that of Cumming, we recognise in the basin the following divisions (here given in descending sequence, but subsequently described in reverse or ascending order):—

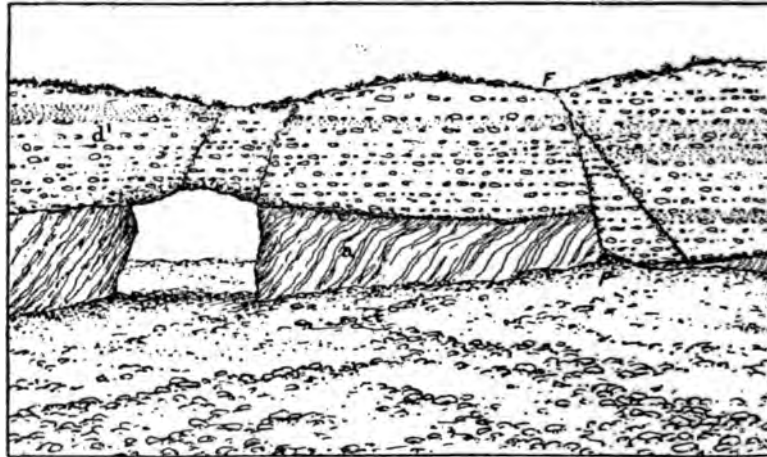
5. Volcanic Series of Scarlet.
4. Posidonomya Beds.
3. Poolvash or Pale Limestones.
2. Castletown or Lower Dark Limestones.
1. Basement Conglomerate.

Basement Conglomerate.

In the south of the Isle of Man it is certain that the vast interval of time between the period of the Manx Slate Series and the earliest stage of the Carboniferous epoch is entirely unrepresented in the succession of the strata. In the north of the Island there remains the slight possibility that some portion of this interval may have its representative among the rocks which lie hidden beneath the drift plain.

FIG. 49.—*Sketch-section of the most northerly of The Arches, Langness, showing unconformability at base of Carboniferous Rocks.*

Height, about 18 feet.



- d¹ Carboniferous Basement Conglomerate.
- a Manx Slates, with red staining.
- F Small fault.

Before the beach-conglomerates were spread out, which in the southern district form the base of the Carboniferous System, the Manx Slates of the central massif, after having undergone the violent structural changes and igneous permeation described in the foregoing chapters, had been cut down to the core by denudation, whereby any intervening strata which may have existed in this quarter must necessarily have been destroyed.

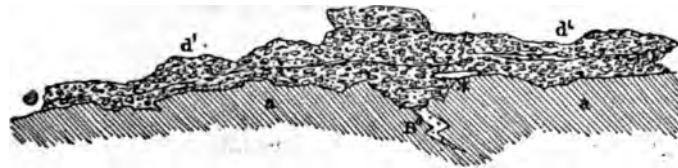
The Carboniferous basement beds are seen to rest upon the denuded edges of the slates in the most conspicuous and striking manner in the coast-sections on Langness. The low cliff at The Arches on the western side of the promontory presents a magnificent illustration of this unconformability, which has

been many times described and figured.¹ The section is so instructive that no excuse is needed for again presenting it (Fig. 49).

Equally or even more impressive are the exposures on the western side of Dreswick Point, half a mile farther southward, where the base of the conglomerate is exactly at the level of the present foreshore, so that as the ancient beach material is loosened and removed by the waves of to-day, the tides once more ebb and flow across the old tidal flat of slate which they washed in Early Carboniferous times. We may tread this ancient feature from high to low water mark, and note how the harder ribs of quartzite and vein-quartz in the slates have formed ridges on the old shore, and how the narrow dykes of greenstone have rotted away into little gullies in the past, just as they still do. After many cycles of change, consuming an interval too vast for us to measure, the old conditions are renewed at this spot; and the sea, unaffected by time, returns once more to roll the Carboniferous shingle over the Carboniferous shore. But a lighthouse now stands guard above it!

FIG. 50.—*Section across foreshore at Langness Point, south of Lighthouse, showing eroded surface of slates beneath Carboniferous Basement Conglomerate.*

Height about 10 feet.



d¹ Carboniferous Basement Conglomerate, filling hollows in the slates :
a large block of grit at * measures 4 ft. by 2 ft.

a Manx Slates.

B⁰ Pre-Carboniferous greenstone dyke, 8 inches wide, along which a gully 3 feet wide and 2 feet deep has been eroded on the Carboniferous shore. This is prolonged into a similar gully on the present shore.

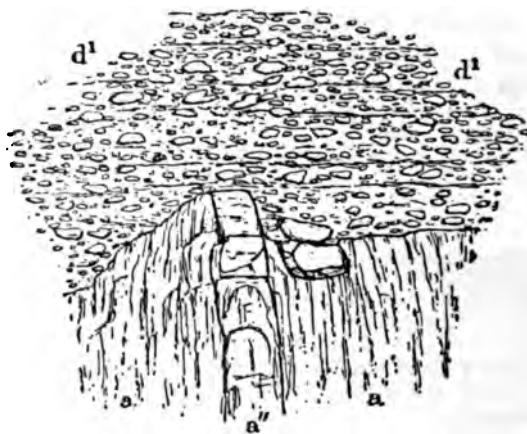
That the Conglomerate has had its origin as a marine beach is proved not only by its general characters but also by its relation to the overlying limestones, into which it passes by gentle gradations. It is chiefly of a dull red colour, and this tint has stained the slates beneath it, to a varying extent, sometimes only superficially and sometimes to a considerable depth. Its pebbles are of all sizes up to a foot or more in diameter, but the majority are smaller than a clenched hand; they are usually well-rounded

¹ Cumming's "Isle of Man," Plate at p. 88; Clifton Ward, *Geol. Mag.* dec. ii., vol. vii., pl. 1; W. W. Watts, "Geology for Beginners," Fig. 156, p. 223.

but occasionally subangular. They may all have been derived from the subjacent rocks,¹ being chiefly of vein-quartz, quartzite and greywacke, with rarer fragments of diabase and slate. In this respect the deposit differs from the pebbly bands in the Peel Sandstone, which contain material not known to exist within the Island (see p. 263). The stones of the Conglomerate are set in a gritty matrix, and in places they are intercalated with lenticular beds of red sandstone. As usual in deposits of this character, the thickness is very irregular and the bedding impersistent. Prof. Dawkins has stated that in the bed of the Awin Ruy, north of Ballasalla, the conglomerate is "about 159 feet thick"; but this estimate certainly exceeds the thickness at other localities.² A measurement across the foreshore to low

FIG. 51.—Section on shore S.E. of last, showing grit-band (a") in slates (a) standing up in a small ridge beneath conglomerate (d').

Height, about 4 feet.



water at the northern side of Derby Haven gives 55 feet of these beds (including 5 feet of gritty limestone marking the upward passage into the limestone), but the conglomerate is not exposed quite to its base in this locality: a mining trial on the western side of Langness passed through about 50 feet of conglomerate before reaching the slate (see p. 538). The only fossils known to occur in it are those recorded by

¹ See W. Boyd Dawkins, "Vannin Lioar," vol. i., p. 16, and Rep. British Assoc., 1896, p. 775.

² "Vannin Lioar," vol. i. p. 17. The figures seem to have been arrived at by calculation from the dip and width of outcrop, as direct measurement is not practicable in this exposure. Cumming was of opinion that "in no place where it can be observed is it more than 50 feet in thickness ['60 feet' in 'Guide Book'], being often not more than 4 or 5 feet."—*Quart. Journ. Geol. Soc.*, vol. ii., p. 320.

Cumming from the uppermost calcareous layers at the back of the Abbey garden at Ballasalla, where a rock consisting of "pebbles of white quartz in a gray matrix of limestone includes the characteristic fossils (particularly *Orthis Sharpei*) of the lowest limestone series as seen elsewhere in this basin."¹

These transitional layers of the Conglomerate are of similar character wherever seen, consisting of thin bands of hard calcareous grit and of limestone with small pebbles. The conditions indicate that with the progressive subsidence, the deposition of limestone commenced in the quieter off-shore waters, while the beach-conglomerate was still creeping upward on the flanks of the slowly sinking land; hence we find that the Lower Limestones are thin and flaggy, and intercalated with thickish partings of somewhat sandy shale, and occasionally contain small isolated pebbles of quartz (see pp. 204, 244). The phenomena are, in fact, analogous to those which generally prevail at the base of the Carboniferous System around the northern part of the Irish Sea, in north-western England, south-western Scotland and eastern Ireland.

FURTHER STRATIGRAPHICAL DETAILS OF THE CARBONIFEROUS BASEMENT BEDS.

(Six-inch Sheets 16 and 19.)

Commencing with the coast-sections at the north-eastern edge of the basin at Cass-ny-Hawin (eastern margin of 6 inch Sheet 16), we find the Carboniferous Limestone brought in suddenly against the slates by a fault striking W. 8 N. with a southward downthrow of approximately 120 feet. At low water of spring tides a narrow strip of conglomerate in proximity to dark gritty limestone may be seen along the line of the fault on the shore. The exposure is not sufficiently clear to show whether this is a wedge displaced between branches of the fault, or whether, as seems very probable, it represents a true emergence of the basement beds below the limestone. A patch of the same rock, mixed with fault-breccia, is seen to accompany the fault in the adjacent cliff. By this dislocation the main mass of the conglomerate is cut out of the coast section and shifted inland for about 300 yards, where its outcrop is exposed in some low crags in the field east of the road to *Ballawoods*² farm, as well as in the road itself and on the western tip of the ravine which the Santon River has excavated in the underlying slates. The upper boundary of the conglomerate is also fixed in this locality by the presence of dark blue fossiliferous limestone in some old quarries in the field to the westward of the above-mentioned road; and as the dips in these exposures are low, say from 5° to 8°, westward, the basement beds must here be comparatively thin.

CASS-NY-
HAWIN.

In following the coast southward from Cass-ny-Hawin, though the limestone occupies the whole foreshore for the next $\frac{1}{4}$ mile, its base is probably never far below low water; and in the outer reef at Loch

¹ "Isle of Man," p. 44. Among Cumming's fossils preserved at King William's College, Castletown, there is a specimen showing *Spirifera glabra*? Mart, in a matrix of limestone with small quartz pebbles. The label gives the locality "Ballahot," a place near Ballasalla where the topmost beds of the conglomerate are slightly exposed (see p. 197).

² As in the preceding chapters, the use of italics in these descriptions denotes that the place-name will be found only on the six-inch Ordnance map.

Skillicore the lowest limestone strata brought up by a slight anticline of a gritty character. A little farther south a small branching fault elevates the crest of the above-mentioned anticline, so that the conglomerate occupies the lower half of the foreshore opposite Ronaldsway. At this place the following section was measured.

I.—Section of base of Carboniferous rocks on foreshore on northern side of Derby Haven opposite Ronaldsway.	Thickness
	Ft. in.
Carboniferous Limestone, blue weathering pale, in lenticular and generally very lumpy beds 6 inches to 2 feet thick; fossils abundant (Productus, etc., corals, encrinites, etc.); thickness (up to low cliff at old limekiln) - - - 38 to 40ft.	
Thin lenticular limestone-courses, smoother and less dolomitized than below - - - - -	6 0
Blue limestone with dolomitized bands and irregular brecciated joints - - - - -	13 0
Calcareous grit or gritty limestone, weathering with curious brecciated aspect (due to irregular dolomitization?) about - - -	5 0
Hard smooth grey calcareous grit, almost like quartzite, with rhomboidal joints - - - - -	2 0
Pebbly conglomerate; thickening northward - - - - -	1 0
Dark soft shaly sandstone with some pebbles - - - about - - -	5 0
Palish blue pebbly grit or quartzite, weathering dark; passes into conglomerate both ways along strike - - - - -	6 0
Very coarse irregular yellow conglomerate, cross-bedded, with sandy streaks; containing boulders of up to 2 feet diameter - - - - -	12 0
Sandy yellow band, smaller stones - - - - -	4 0
Alternations of sandy and coarse bouldery conglomerate, yellowish, stained red in places - - - - -	8 0
Yellow conglomerate, in some places sandy in others coarse, with subangular stones over 1 foot diameter - - - - -	6 0
Coarse red conglomerate - - - - -	6 0
Lower beds visible beneath sea at low water.	

NOTE.—All the beds of conglomerate are very impersistent and changeable, so that the details vary from point to point.

DERBY HAVEN

In crossing Derby Haven a slight depression reduces the Basement Bed to a narrow strip just visible at the lowest tides on the outer side of the Breakwater; but they afterwards creep upwards again, so that 100 yards south of the Breakwater their base is exposed, resting upon an uneven surface of stained slate. The steeper dip, of about 30° towards W.N.W. at this place, in the vicinity of a fault, quickly brings on the overlying sandy limestone, the whole outcrop of the conglomerate having a width of about 40 yards. The foreshore is, however, so much obscured by beach material and seaweed that only a small portion of the deposit can be studied.

The small fault just referred to has been taken possession of by an olivine-dolerite dyke; its effect is to bring the lowest beds of the limestone against the conglomerate in the middle of Derby Haven, and to shift the outcrop of the latter 100 yards eastward, where the rocks are for the most part hidden under beach-material. The S.S.W. prolongation of the anticline noticed at Skillicore and Ronaldsway is again intercepted by the coast on the southern shore of Derby Haven; and is succeeded eastward by

a shallow syncline which brings in a small trough of sandy limestone flanked on both sides by the conglomerate. The most easterly exposure of the Basement Beds in Derby Haven is at high-water mark a few yards east of the gate across the road to St. Michael's Island, where coarsish conglomerate is seen in contact with stained slate; but whether the junction is normal, or slightly faulted, is not clearly shown. Crossing the isthmus of sand-dunes, less than 200 yards in width, which separates Derby Haven from Castletown Bay, we find a broad flat foreshore on which the line of disturbance above noted can again be recognised, the anticline breaking into a small fault and uplifting a little pear-shaped inlier of pebble-beds, traversed by two small olivine-dolerite dykes, among the lowest limestones. The main belt of conglomerate is magnificently exposed 150 yards farther southward, being continuous thence along the shore nearly to the southern extremity of Langness. In these extensive surfaces, showing a confused admixture of large and small stones and pebbles, interspersed with seams of sand, its beach-like character is most impressive; and the interest of the scene is heightened by the presence of a plexus of black olivine-dolerite dykes ramifying among the red conglomerate. Towards low-tide mark, the rocks are cut up by water-channels and obscured by a heavy growth of seaweed; but in spite of these difficulties it is possible to trace the sandy upper margin of the conglomerate passing up into gritty limestone, as far southward as Greg Inneen Thalleyr, but south of this spot the conglomerate extends to low-water.¹

LANGNESS

One of the trial shafts of the Langness Copper mines (see p. 538), 300 yards S. of Langness Farm, a few feet above high-water mark on the raised-beach platform, starting in the upper part of the Basement Beds, penetrated 50 feet of these beds and then entered the slates. A small fault brings up the slates, on the E., against the conglomerate, in the bank below the Langness farmstead; and a similar faulted junction occurs nearly on the same line 450 yards further southward, on the western side of the low cliff at the Copper Mine buildings. The main shaft of the mine was sunk in the slate at this place; but a level at a depth of 12 fathoms went N.W. to the fault, and reached the conglomerate and one of the olivine-dolerite dykes; a second level at 25 fathoms was entirely in slate (p. 538). South of the mine, the slates occupy the low cliff and the upper part of the shore for a distance of 400 yards, when the beds are again affected by a small fault which brings the conglomerate into the cliff-section at The Arches, as shown in Fig. 49, p. 190.

The small dyke, supposed to be of the age of the Carboniferous Volcanic Series, which traverses the slate and the conglomerate on the shore immediately to the northward of The Arches, has been elsewhere described (see p. 325).

From this place to *Port Bravag* in the northern elbow of Langness Point, the picturesque cliff and foreshore are composed entirely of conglomerate; and a level had, in 1895-6, been driven eastward for 36 fathoms into the cliff at the southern end of The Arches without reaching the slate. At *Bravag* the base of the conglomerate again rises above the shore, and passing over the ridge of slate which forms Langness Point descends gradually on the southern side to low water at Dreswick Harbour, where the main belt occupies a strip of the coast 160 yards wide, with several small outlying cake-like masses resting upon the upturned edges of the slate between high and low water marks. The chief features of these fine exposures have already received our attention (pp. 191-2, Figs. 50, 51).

We do not again find the base of the Carboniferous rocks revealed on the coast. But at the western edge of the basin, 4½ miles W. of Langness, the calcareous top of the conglomerate is just visible in the outer harbour at

PORT ST. MARY.

¹ The characteristic differences between the foreshores formed respectively of limestones, conglomerates, and slates on the southern coast of the Island are expressed on the Ordnance maps by different ornamentation. This is on the whole well done, though the boundaries are often not quite correct. The larger olivine-dolerite dykes are also sometimes indicated.

Port St. Mary between tide-marks, at the edge of the fault which forms the landward boundary of the isolated patch of Carboniferous Limestone. The presence of the conglomerate in this locality was noticed by Macculloch¹ and Henslow², but was overlooked by Cumming³ and subsequent writers. It occurs as a narrow strip parallel to the fault, the following being the downward succession :—

- Black sandy limestone (extending up to the New Pier.)
- Dark pebbly grit, 3 inches.
- Brown sandy grit with pebbles, 1 to 2 feet.
- Dark gritty limestone, 2 feet.
- Fault—bringing in the Slates.

The same calcareous pebbly beds were found below low-water in preparing the foundations for the extension of the pier at this place in 1893. Mr. James Walker, C.E. informed the writer that the divers were at work here on a low submerged cliff, 6 to 8 feet high, the upper part composed of limestone, and the lower of the pebbly rock. Specimens procured for the Survey by the divers, under Mr. Walker's instructions, consisted of pebbly conglomerate of rounded fragments of vein-quartz set in a dark gritty calcareous matrix, the pebbles being somewhat larger than those in the outcrop on the foreshore. The rock resembles the topmost layers of the conglomerate exposed at Ballahut and Ballasalla in the interior.

The presence of the top of the Basement Beds in this quarter, together with other evidence mentioned below, seems to indicate that the boundary-fault which cuts off the Limestone-basin westward may owe its strong effect upon the stratigraphy, not so much to the amount of its vertical displacement as to its position near the base of the Carboniferous Series in its present line of outcrop.

ARLET.

At Scarlet Point the disturbed mass of limestone adjacent to the Volcanic rocks contains, in one part, a seam of scattered pebbles of quartz, suggesting that it may include portions of the lowermost limestone beds. Its present anomalous relations will be subsequently discussed (p. 244).

LAND
POSURES.

Along the north-eastern margin of the limestone-tract in the interior, the Basement Beds are well displayed at several points. In the road-cutting at Ballakewin, 200 yards south of Athol Bridge, coarse red conglomerate is revealed, resting on stained slate. The ground to the westward of this exposure is covered with drift; but red conglomeratic rubble probably marking a weathered outcrop was noticed in the gutter adjoining the ruins of a cottage 350 yards W.S.W. of Ballavell; while in the same gutter about 70 yards farther north-westward the solid slate is reached. The soil in the S.W. corner of the next field westward seems again to indicate that the conglomerate is close to the surface; and on this evidence the westerly curve has been drawn in its boundary on the map. The facts suggest that at this place its limits have not been much curtailed by the boundary-fault.

Forty yards below Athol Bridge the conglomerate is visible in the bed of the Silverburn, with limestone above it in the eastern bank. In the adjacent field the decomposed limestone was formerly dug for the manufacture of umber⁴. These Carboniferous rocks form a small outlier cut off by a fault running approximately in the direction of the valley, or nearly at right angles to the main Carboniferous boundary-fault. As the ground to the eastward is drift-covered, the evidence in regard to this outlier is confined to the immediate neighbourhood of the stream-bed and that of a little tributary; and the mapping is therefore necessarily more or less conjectural. The complications extend down to the village of Ballasalla; the rendering of the ground finally adopted, after repeated examination, agrees closely with that given by Cumming. Gritty limestone and sandy shale is visible in the little tributary of the Silverburn on the

¹ "Western Isles," vol. II., p. 569.

² Trans. Geol. Soc., vol. V., p. 492.

³ "Isle of Man," p. 143.

⁴ A shallow excavation for this purpose was in progress in 1892, when the ground was surveyed.

eastern side of Ballashimmin; but there is no exposure of the outer belt of conglomerate indicated on the map at the north-eastern margin of the outlier, though the presence of conglomerate-rubble in the drift in a gutter 150 yards north-east of Ballashimmin supports the likelihood of its existence. The outlier appears to be bounded on the south-east by a third dislocation, having a N.E. course parallel to the principal boundary-fault; the evidence being that at the sharp bend of the Silverburn 200 yards N.W. of *Cregg Mill*, slate is exposed at the foot of the slope (close to the building used in 1893-4 as a Mineral-water Factory) and in the road leading down it, while gritty limestone dipping to south-west occurs in the bottom of the stream on the north-west side of the bend, and is succeeded downward by fine pebbly conglomerate and then by coarse conglomerate; and these rocks are replaced suddenly by quartzite belonging to the Manx Slates at the turn of the curve. Thence to *Cregg Mill* the stream runs in a gully carved out of quartzite and slate; but its course must lie very near the line of the N.W. and S.E. fault, as the following downward succession can be made out in the northern bank of the road up the slope east of the mill.

Dark Limestone (in place?) at bend at top of slope.

* * * * (gap of several feet, not seen);

Fine-grained calcareous grit.

* * * * (gap of a few feet);

Bands of calcareous grit with layers of small pebbles of quartz.

* * * * (gap of a few feet);

Conglomerate with rounded and sub-angular stones up to 4 inches in diameter, 13 to 5 feet seen.

* * * * (gap of several feet, not exposed);

Slate and quartzite (Manx Slate Series) forming the foundations of the bridge.

The fault crosses the stream 150 yards below the mill, where conglomerate and pebbly limestone are slightly exhibited in the bed of the stream, while slate and quartzite are exposed in the western bank. A short level has been driven into the latter rocks in search of iron-ore (p. 484). A little lower down the valley there are a few exposures of limestone, to which later reference will be made.

Awin Ruy, the tributary which falls into the Silverburn from the north-east at the northern end of the village of Ballasalla, flows at right angles to the strike of the main belt of Basement Beds and these rocks are revealed in several places in its bed. At the mainroad-crossing the stream is in dark limestone dipping gently towards S.S.W.; 100 yards farther north pebbly limestone is seen, followed by sandstone, marking the upper limit of the conglomerate; and another exposure 400 yards north of the mainroad shows pebbly sandstone interbedded with coarse conglomerate, resting upon or against purple-stained quartzite of the Slate Series¹. The altitude of the quartzite in the walls of the ravine just above the junction of this rock with the conglomerate suggests slight faulting, or otherwise considerable unevenness of the old surface beneath the conglomerate.

From these exposures to those in the vicinity of Cass-ny-Hawin already described, a distance of $1\frac{1}{4}$ mile, the outcrop of the Basement Beds is completely hidden by drift.

To the westward of the Silverburn only two outcrops remain to be noticed. Pebbly limestone and fine quartz-conglomerate are exposed in the bank on the western side of the gardens of Rushen Abbey, at which place, as noted above, Cumming found fossils of the Lower Limestone series in the pebbly rock. Similar material crops up in the road at the farm of Ballahot, $\frac{1}{2}$ mile farther westward, furnishing evidence of the upper limits of the Basement Beds in this quarter.

¹ See p. 192 and footnote, with reference to the supposed thickness of the Basement Beds in these exposures.

Lower or Castletown Limestone.

In extent and thickness the Lower Limestones constitute by far the most important division of the Carboniferous rocks of the south of the Island. They consist of flaggy courses of dark blue limestone, from a few inches to a few feet in thickness, separated by partings of black shale, which are thickest and most numerous towards the base of the division. Thin lenticular patches and nodules of chert are locally abundant at certain horizons, especially towards the top of the division on the coast west of Castletown Harbour. In the lower part fossils are plentiful, comprising many common Carboniferous Limestone forms (see table at end of chapter, pp. 257-62); the higher beds contain fewer fossils, but in them are found certain species like *Prolecanites compressus* (*Goniatites Henslowi*) and *Nautilus* (*Discites*) *complanatus* which are of more restricted distribution.

The differentiation of the division from the higher portions of the limestone series, though grounded principally upon lithological characters, appears to rest also upon a sound palæontological basis. An adequate investigation of the latter branch of the enquiry would however have consumed more time than could be allowed for the survey of this limited tract; so that we are still compelled to rely principally upon the previous work of Cumming for information in regard to the distribution of the fossils, supplemented by a few notes most kindly prepared for us by Dr. Wheelton Hind from his personal knowledge of the deposits (see pp. 254-6).

The following passages are quoted verbatim from Cumming, and contain his analysis of the subject as given in the notes which follow his lists of Manx Carboniferous Limestone fossils ("Isle of Man" Appendix Q, p. 358).

"In order to show a reason for the separation which I have made of the Carboniferous limestone series of the Isle of Man into three divisions of—1st, *Lower limestone*; 2nd, *Poolvash limestone*; 3rd, *Posidonian schist*, it will be sufficient to call attention to the following facts.

"Of the 222 species named and located in [the fossil list] we have only 30 common to 1st and 2nd; only 8 common to 1st and 3rd; only 11 common to 2nd and 3rd; only 3 common to 1st, 2nd and 3rd. Again, of the 76 species occurring in 1st, 40, or more than 50 per cent., are found in it only. Of the 153 species occurring in the 2nd, 117, or 76 per cent., are found in it only. Of the 39 species found in the 3rd, 20, or just 50 per cent., belong to it alone.

"The fossils characteristic of the lower limestone series seem to be *Orthis Sharpei*, *Productus hemisphaericus*, *Caunopora ramosa*, *Favosites ceteles*, and the larger variety of *Cyathophyllum fungites*.¹ The localities for obtaining them are the little creek of Ronaldsway, Strandhall to the westward of Poolvash, and Port St. Mary. At Scarlet, near the limekilns, the specimens of *Ammonites Henslowii* and *Nautilus complanatus*, which are in the Woodwardian Museum, Cambridge, were obtained. I am not aware that the latter fossil has elsewhere been found."

In another part of the same volume (p. 241) Cumming makes the following statement in regard to the wider correlation of the Lower Limestone:

¹ For modern terminology, see Notes and List at end of chapter.

"On a comparison of the fossils of this division with those of the carboniferous series in other parts of the British Isles, we find them remarkably agreeing with the lower Northumbrian type, or still more closely with the series developed in the neighbourhood of Hook Point in the south of Ireland; they may very well be compared also with the Kendal beds" (see also p. 208).

The gradual downward passage of the Lower Limestone into the Basement Conglomerate has already been described. Its upward limits and relation to the Poolvash Limestone are ill-defined; they will be more conveniently dealt with in discussing that division (see p. 210). Cumming estimated the thickness of the Lower Limestones at not more than 160 feet¹, but it will be subsequently shown that this is probably too low. These rocks occupy the whole of the southern Carboniferous basin within the rim of Basement Beds, except a narrow strip bordering the coast between Scarlet Point and Balladoole, where alone are the higher divisions and the Volcanic series preserved.

FURTHER STRATIGRAPHICAL DETAILS OF THE LOWER LIMESTONES.

From Cass-ny-Hawin, where the basal beds of the Lower Limestones are faulted down against the slates under conditions stated on a foregoing page, the division occupies the whole of the foreshore and low cliff up to Ronalds-
CASS-NY-HAWIN TO DERBY HAVEN.
 way. Cumming has given a minute and accurate account of this part of the coast, with an enlarged ground-plan showing the system of small faults and flexures by which it is characterized.² The governing dip is towards W.N.W., but this is subject to incessant variation owing to the above-mentioned disturbances, the general effect of which is to throw the limestone into a succession of shallow basins and low domes, with steeper plications which occasionally break into actual faults. The flaggy character of the bedding brings out these features very clearly on the broad foreshore. The axis of disturbance alluded to in discussing the conglomerate runs S.S.W. from the vicinity of Cass-ny-Hawin, where it appears to be a true fault, to Skillicore, where it takes the form of a sharp narrow anticline with some crushing of the limestone but perhaps without actual dislocation. Opposite Ronaldsway it enters the conglomerate and its course thence has already been traced. Other minor lines of crush and slight faulting, sometimes crossing each other with a rudely reticulate arrangement, strike in directions varying between W.S.W. and N.W. Dolomitization of the limestone has gone on extensively along these disturbances, and sometimes spreads out from them along the bedding-planes. Small veins of calcite, quartz and dolomite are common, and at Skillicore a mass of shattered and stained limestone has been recemented by vein-material into a belt of "beautiful variegated appearance," as noted by Cumming,³ who says that "some attempts to work it as a marble-quarry have been defeated by the large admixture of quartz, and the fractured character of the rock."

A marked feature of these flaggy limestones is the lumpy lenticular character of the bedding, the upper surface of many of the courses being embossed with rounded protuberances, from a few inches to a few feet in diameter, often rising several inches above the general level. These are still more strongly developed at the same and higher horizons farther westward. They seem to be original structures of the beds, due to the presence of masses of coral or clusters of shells, though it is only occasionally that

¹ Quart. Journ. Geol. Soc. vol. ii., p. 320.

² Quart. Journ. Geol. Soc. vol. ii., pl. xvi. and "Isle of Man," pl. at end.

³ "Isle of Man," p. 106.

the organic remains are still preserved in them. The subject will be subsequently referred to in relation to some anomalous features in the Poolvash Limestones (see p. 250.)

The following section was measured in 1892 on the foreshore and foot of the cliff between Cass-ny-Hawin and the Skillicore disturbance. The measurement was rendered somewhat doubtful in places by the disturbances of the strata; but the section gives approximately the succession and the thickness of the beds above the conglomerate on this part of the coast. It will be seen that a thickness of about 150 feet of limestone and shale is represented.

II.—Section of Carboniferous Limestone on the shore between Cass-ny-Hawin and Skillicore.	Thickness
Limestone courses with thickish shale partings, seen in foot of cliff N. of Skillicore; beds to southward much confused by small faults, but probably no higher strata exposed up to the Skillicore disturbance	<i>Pt. in</i> 8 0
Limestone courses, weathering rough, with thin partings of shale: small encrinites and large corals abundant: in reef and cliff N. of Skillicore	12 6
Alternations of rhomboidal-jointed flaggy limestone, and shale. Encrinites and other fossils abundant; reticulate corals plentiful in lower part	15 0
Limestone band with conspicuous rhomboidal structure	1 0
do. weathering rough	1 6
Alternations of thin platy limestone and shale	10 0
Beds hidden by shingle	10 0
Shaly beds with thin limestone. Productus, etc., abundant	5 0
Alternations of thin shaly limestone with thicker paler limestone courses. The shale bands contain curious nodule-like lumps of limestone. These beds form a reef in small bay S. of Cass-ny-Hawin	10 0
Thicker limestone-courses, very irregular; interrupted by small fault	7 0
Dark-blue thin limestone bands with shale partings; bedding lumpy and lenticular; corals, encrinites, and other fossils	9 6
Shale	0 6
Thicker limestone courses	4 6
Lenticular lumpy limestone bands with shale partings	4 6
Shale with thin platy limestone	2 0
Thin irregular limestone bands with thin shale partings	4 0
Palish blue limestone, weathered with rough surface; forming top of reef on south side of Cass-ny-Hawin fault	2 0
Dark limestone in thin lumpy bands with shale partings	7 0
Dark greyish limestone	3 0
Dolomitized massive limestone, confused by fault, and thickness doubtful	say 25-30
Basement Conglomerate. Top just seen on beach near low water at Cass-ny-Hawin, S. of fault bringing up Manx Slates	

The exact effect of the interruption at Skillicore has not been determined, but the amount of displacement is not likely to be more than a few feet, probably causing a slight repetition on the western side. Between this place and the Ronaldsway fault, which breaks the upward sequence by bringing in the lower beds again, the following details were noted, showing

an additional 40 feet or so of higher strata, and thereby considerably exceeding Cumming's estimate for the whole thickness of the Lower Limestones.

III.—Section of Carboniferous Limestone on the shore between Ronaldsway and Skillicore.	Thickness.
	<i>Ft. in.</i>
Thin limestone bands and black shale, with large <i>Productus</i> , etc.; on shore of Ronaldsway inlet and in cliff at north side	4 0
Thicker paler limestone bands, many fossils	3 0
Shale	0 6
Dark grey limestone, weathering pale; many small brachiopods	3 0
Shale with nodule-like lumps of limestone	0 6
Thin platy limestone bands, lumpy and lenticular; many <i>gasteropods</i> in upper layer	4 0
Shale	0 6
Hard blue limestone in lumpy lenticular courses, with thick shale partings; many fossils	12 6
Hard limestone-course, with surface covered with 'fucoid' markings	1 0
Dark limestone courses with thin shale partings	8 0
Dark limestone courses with thin shale partings, very lumpy in lower part; extends up to Skillicore disturbance, and probably overlaps top of Section II.	10 0
Thinly-bedded shaly limestone seen below this at low-water S. of disturbance	

The upper surface of the limestone in the low cliffs north of Ronaldsway is sometimes decomposed into brown 'umber'. A group of small branching olivine-dolerite dykes traverse the foreshore in a north-westerly direction at the northern termination of Loch Skillicore (see p. 330).

The details of the interesting section on the foreshore opposite Ronaldsway in which the lowermost layers of the limestone pass down into conglomerate have previously been given¹ (see p. 194).

In the inner portion of Derby Haven the sandy foreshore is probably underlain in places by boulder-clay covering the limestone, but the latter rock crops up here and there in low scars. On the outer side of the Breakwater it is traversed by two small olivine-dolerite dykes, and by a third in the line of fault already described, 140 yards S. of the Breakwater (p. 330). The short infolded trough of limestone among the conglomerate on the southern shore of the Haven has been previously mentioned.

On the eastern side of Castletown Bay the lowermost portion of the limestone is exposed at dead low-water on Creg Inneen Thalleyr, and from this point northward the outcrop expands until it occupies the whole of the shore, here over quarter mile wide at low tide, but much obscured by seaweed. The dip is usually about W.N.W. at an angle of 10° or under. A few dolomitized veins occur, mostly striking approximately E. and W., and are accompanied by slight crushing; while at low water in the bend of the Bay, 80 yards N. of *Black Rock* (6-inch map, Sheet 16), a good example

¹ Cumming describes "a tabular mass of trappean conglomerate, or of quartz pebbles, apparently mixed up in a trappean matrix" as occurring in this section between the limestone and conglomerate, and colours it as an igneous rock on his published ground-plan. His description evidently refers to a dark pebbly crystalline calcareous grit which occurs in places in the position indicated.

of the domed arrangement of the bedding may be noticed ; but the strata as a whole are much less disturbed than in our former sections. They are traversed by several small dykes of olivine-dolerite, having the usual north-westerly strike, which appear to occupy discontinuous parallel cracks or joints.

BOES.

The two islets bared at dead low-water about a half-mile off shore in this part of the Bay, known as *Sandwich Boe* and *Boe Norris*, are composed of dark flaggy limestone. As seen from the shore at low water of spring tides, one would imagine that a good stretch of rock was exposed in these reefs, but the appearance is mainly due to the laminaria-weeds growing thickly on their submerged portion and rising up out of the water surrounding them; with a tide of about 19 feet only three narrow ridges of bare rock were found on *Sandwich Boe*, while on *Boe Norris* the rock exposure was confined to one small boss a few feet in diameter. A larger reef, *Lheeah Rio*, half mile S.W. of *Boe Norris*, is shown on Cumming's map as limestone ; but so far as I have been able to examine it, with an ebb-tide of 18 or 19 feet, the whole outcrop consists of dark basalt or olivine-dolerite (see p. 326).

The inner shore of Castletown Bay for five-sixths of a mile, from the N.E. corner at *Sandwich* (six-inch, Sheet 16) to within about 100 yards of the harbour, is usually covered with sand and shingle ; and when this is swept aside hard stony till is revealed. No evidence is forthcoming as to the depth to which the limestone lies buried in this gap, but it is not unlikely that the interval may conceal a preglacial or early-glacial rock-channel, perhaps that of the old Silverburn, filled in with drift. The embouchure of the Silverburn at Castletown Harbour is a narrow post-glacial notch excavated in the limestone ; and as its valley as a whole is a pre-glacial feature, its present course here is evidently not that which it once occupied.

The solid rock reappears near high-water mark 70 yards west of *Plucking Pool*, and is more or less continuous thence to the harbour, though on the shore below about half-tide level boulder-clay was seen in several places. To the westward of the Harbour the greater part of the tidal platform is composed of bare limestone, which is continuous thence to *Scarlet*. Above high-water immediately to the westward of the Pier, the strata are more thickly bedded and paler than is usual in the Lower Limestone. They are probably near the top of the division, and may foreshadow the upward passage into the pale Poolvash Limestone which was recognised by Cumming¹ 600 yards farther westward, in the field north of *Knockrushen House*. The dip of the beds, however, is variable and the rocks are intersected by lines of crushing and dolomitization in this vicinity, so that it is difficult to make out the true sequence ; and though this limestone is presumably higher than any hitherto described, its actual position in the series cannot be directly determined. A systematic study of the fossils of the whole series might possibly yield this information, as some of them appear to be confined to definite horizons.

A branching group of small olivine-dolerite dykes is visible in the limestone in the outer harbour 25 yards N.E. of the Pier, and Cumming noticed "thin strings of galena" in association with the intrusion. Opposite *Knockrushen House* the foreshore is traversed by a dyke of the same rock-type, from 18 to 24 feet wide, with several thin fliers in the limestone outside its margin ; it strikes W. 12 N. and is the broadest example of its class. One hundred and fifty yards farther south another of these intrusions, only a few inches wide, is encountered ; another of similar small dimensions 80 yards beyond ; and another, in a decomposed and scarcely recognizable condition, among disturbed limestone at the landing place opposite *Scarlet House*.

A more important but less accessible mass of igneous rock occurs in the lowest reef of the foreshore, E. 5 S. of *Scarlet House* and 320 yards south of *Seal Rock*. This reef² though shown on the Ordnance map as if contin-

¹ Quart. Journ. Geol. Soc. vol. ii, p. 334.

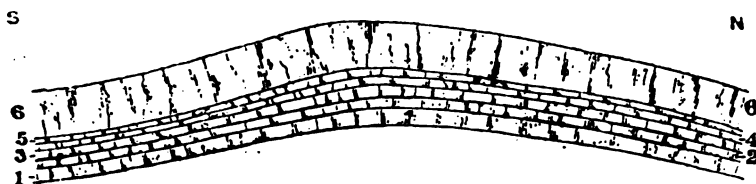
² The reef is not named on the Ordnance maps, but is known to the fishermen of Castletown as Creg Kermode.

nous with the shore is only exposed at the lowest spring tides, and then can rarely, if ever, be reached except by boat. Dark flaggy limestone constitutes the chief part of the reef, and into this is intruded a mass of dark basaltic rock somewhat resembling that of the insulated Lheeah Rio out in the Bay 500 yards to the south-eastward; it belongs either to the olivine-dolerite dykes, or to the Scarlet Volcanic group, the latter being the more probable (see p. 325). Owing to the heavy growth of seaweed with which the reef is covered, the limits of the intrusion are difficult to trace, but it seems to form a boss 20 or 30 yards in diameter, truncated by the sea, narrowing westward into a dyke a few feet wide, perhaps continuous with that above-mentioned at the landing place opposite *Scarlet House*.

Several dolomitized veins occur in the limestone between Castletown and Scarlet. The general inclination of the strata in this area is towards W.N.W., but with many local disturbances in which the rocks are often elevated into small domes with quaquaversal dips, having a flattened circular or oval summit. More or less perfect examples of this dome-structure are visible in the low-water reef of *Seal Rock*; near high-water in the recess opposite *Scarlet House*; and on the narrow foreshore between *Scarlet House* and *Scarlet Point*. We shall have occasion to revert to this structure in discussing the 'knoll-structures' of the Poolvash Limestone and of the Volcanic Series. The following section through one of these domes, in the low cliff 200 yards S.W. of the Scarlet Limestone quarry, reveals a slight thickening of each component stratum on the crest of the arch.

SCARLET.

FIG. 52. Section through crest of anticline in dark limestone with thin shaly partings, in low cliff north of Scarlet Point. Height about 8 feet.



The thickness of the individual bands of limestone varies as under:—

	South side.			Centre of dome.			North side.	
Bed No.	6	... 43 inches	...	43 inches	...	43 inches	...	43 inches
"	5	... 5½ "	"	8½ "	"	4½ "	"	4½ "
"	4	... 6 "	"	8½ "	"	6 "	"	6 "
"	3	... 10 "	"	12 "	"	10½ "	"	10½ "
"	2	... 8 "	"	9½ "	"	8 "	"	8 "
"	1	... 13½ "	"	15½ "	"	14½ "	"	14½ "
Totals		85½ "		97 "		83½ "		83½ "

The quarry above-mentioned, which produces both building-stone and road-material, shows an excellent section in dark blue limestone-courses with black shaly partings, gently undulating as on the adjacent foreshore; and the upper surface is well-glaciated (see p. 465). These are probably the higher beds of the Lower Limestone; among the fossils which they have yielded (see list, p. 257) the most interesting are the rare cephalopods—*Prolecanites compressus* (*Goniatites Henslowi*), *Solenoceras pentagonus*, *Ephippioceras bilobatum*, *Actinoceras giganteum*, *Pleuromutilus? scarlet-*

tensis, the last-named a new species recently described by Mr. F. R. Cowper Reed¹.

The same limestones extend for 300 yards farther southward, and are then broken off against the Volcanic Series, in a section which will be discussed on a later page.

Cumming states² that he measured accurately the Lower Limestone in this vicinity and found that down to low-water mark the thickness amounts to 129 feet; and he would allow only 50 feet more (which is probably insufficient) for the thickness below low-water mark to the base of the limestone, thus obtaining "in round numbers 180 feet for the dark limestones and shales at the Stack of Scarlet."

NY
HICKRY.

From Scarlet Point to Poyll Vaaish (Poolvash), a distance of $1\frac{1}{4}$ miles, the Volcanic Series occupies the coast; and from Poolvash for one-third of a mile westward, the Upper or Poolvash Limestone forms the principal constituent of the sections, though some patches of the Lower Limestone may possibly be intermingled with it (see p. 214). A N. and S. fault which ranges along the foot of the low cliff near Balladoole, south of the Castletown and Port St. Mary highroad, in crossing the broad scar to low-water opposite *Poyll Ritchie* brings up the Lower Limestones on its western side, and they are continuous thence on the shore to the westward for two-thirds of a mile, until let down against the slates by the boundary-fault at Kentraugh. The limestone strata of this tract resemble the beds between Ronaldsway and Cass-ny-Hawin both in composition and in fossil contents, and probably represent a similarly low horizon in the division. A rounded quartz-pebble, one-third of an inch in diameter, was observed in one of the limestone-bands a few yards to the westward of the fault.

The olivine-dolerite dykes traversing this part of the coast are evidently the prolongation of those of Langness and Castletown which have crossed the drift-covered interior between the bays. The largest among them, 18 feet wide, may be continuous with that of Knock-rushen; it crosses the little bay at *Strandhall* from side to side in a north-westerly direction, first emerging at *Poyll Breinn* on the east and plunging inland again 100 yards west of the mill at *Strandhall* (six-inch map, Sheet 16). A smaller dyke west of *Poyll Ritchie* may be traced along the line of the fault above-mentioned for over 200 yards, this evidence apparently implying that the intrusion was of later date than the dislocation; yet on an adjacent part of the shore, other two small dykes of the same character, striking W.N.W., appear to be shifted several yards southward by the same fault.

On the beach opposite the place where the Castletown road turns inland, the limestone-scars are broken by a channel in which, when the recent shingle is denuded off, peat with trunks of trees is exposed and is said to be continuous to low water (see p. 413); this was evidently the channel of the *Strandhall* stream when the land stood higher than at present.

Between *Strandhall* and Kentraugh the general dip of the limestone is eastward, with broadly curving undulations; on this part of the shore the limestone has been quarried. The lumpy surface which often characterizes the bedding planes appears to be due mainly to large *Producti* and turbate corals (*Zaphrentis*) embedded in the rock.

In approaching the boundary-fault we find patches of till resting on a scratched surface of the limestone on the shore; and similar material forms the low cliff above. This suggests that the tidal rock-platform has existed in Preglacial times and is not yet completely laid bare again. The limestone may be traced to within about 20 yards of the slate, but the actual fault-line was not visible at the time of the Survey, being everywhere hidden by till and beach-material. The exposure of limestone nearest the fault is a patch of black gritty rock, visible at about half-tide level, possessing the characters of the lowest beds of the series; and it is probable that the lower part of the shore may contain the actual base of the limestones, as at Port St. Mary.

¹ Geol. Mag. dec. iv. vol. vii. (1900), pp. 105-6. pl. vi.

² "Isle of Man", p. 126.

The Carrick is an insulated rock exposed at low-water in Bay ny-Car-**THE** rickey, three-quarters of a mile off shore due south of Kentraugh; it is com- **CARRICK.** posed of dark flaggy fossiliferous Lower Limestone, with gently rolling dips forming a low anticline on an E.N.E. to W.S.W. axis.

The prolongation of the boundary-fault across the bay brings in an outlier **PORT ST.** of the limestone on the tip of the headland between Port St. Mary and **MARY.** Perwick Bay. The lowermost portion of this outlier,¹ in Port St. Mary Harbour, has already been described. The upward succession on the outer side of the new pier is shown in the following section, measured on the foreshore; it reveals a thickness of 70 to 80 feet.

IV. Section of Carboniferous Limestone in the outlier at Port St. Mary.	Thickness.
	<i>Ft. in.</i>
Palish Limestone; many encrinites and 'fucoid' markings; highest bed visible on shore east of boundary-fault - - -	3 0+
Lumpy courses of palish limestone with thin shale partings; in cliff opposite new houses - - - - -	14 0
Lumpy irregular courses of limestone with very thin shale partings; fossils abundant; in cliff east of old limekilns - -	22 0
Palish Limestone with thin shale partings; corals abundant; on shore opposite old kilns - - - - - about	8 0
Calcareous shale with lumpy nodule-like structure; many corals - - - - -	2 0
Dark limestone courses with lenticular bedding and very lumpy surface; thickish shale partings; large corals, etc.; in cliff south of new breakwater - - - - -	10 0
Two bands of dark limestone, each 1 ft. thick, forming slope abutting on breakwater - - - - -	2 0
Limestone hidden by breakwater and within harbour, up to the band with quartz pebbles, see p. 196 - - - probably about	20 0

In the upper part of this section the shale-partings are fewer and the limestone courses correspondingly thicker and also paler in colour than at the same horizon on the eastern side of the basin. The lumpiness of the bedding planes is very prominent, especially in the little recess due W. of *Kallow Point* (6-inch map, Sheet 16). The dips are undulatory, perhaps from the proximity, of the fault; but the dome-like arrangement so strongly marked in other parts of the limestone basin is only slightly developed in the outlier. The actual junction of the Carboniferous rocks with the slates at the fault is visible for a short space both in the outer harbour and on the shore at the S.E. extremity of Perwick Bay. In the latter locality the dislocation contains masses of fault-breccia, and the limestone is in places decomposed to brown earth or 'umber.'

INLAND EXPOSURES.

The inland extension of the Lower Limestone lies wholly within Sheet 16 of the six-inch map. Returning to the eastern margin of the basin, we find a shallow exposure in the old limestone quarries already referred to (p. 193) in the lowermost beds quarter of a mile inland from Cass ny-Hawin. The next outcrop from beneath the drift is two-thirds of a mile farther west, **SOUTH-E** where some hollows in a field 500 yards S.W. of Ballahick, in which the soil **OF BALL** contains angular fragments of dark limestone, seem to indicate old quarries. **SALLA.**

¹ Though always spoken of as an outlier, this is not strictly speaking correct, since the limestone is almost certainly continuous eastward beneath the sea with the main outcrop.

Similar appearances recur in another field 500 yards farther west, adjoining the Douglas and Castletown main-road 120 yards N.E. of the milestone ("Douglas : eight miles"). To indicate these two small areas on the one-inch drift map a continuous line has been drawn surrounding them ; but there is probably a considerable thickness of drift in part of the ground between them. The little stream draining from Ballahick to Derby Haven is probably close to the surface of the limestone for the space of 300 yards to the southward of the bridge on the road to Ronaldsway. Bare limestone is revealed in its bed near the place where the sluice draws off the water for the Ronaldsway dam, 900 yards S. of the bridge. The rest of the country E. of the Castletown main-road is drift-covered.

In the bed of the Silverburn between Castletown and Ballasalla there are at intervals slight exposures of dark flaggy limestone between 100 and 800 yards N.N.E. of the foot-bridge west of Creggans ; and a small excavation on the E. side of the railway 600 yards N. of the bridge shows boulder-clay resting on a glaciated surface of the limestone. Creggans Hill, S.E. of this place, though mainly a drift-feature, is probably moulded on a core of limestone. The same rock is exposed again in the shallow railway cutting 450 yards W.S.W. of Ballasalla Station, and in both banks of the adjoining stream. It is seen at several places in the main street of Ballasalla ; around the buildings at the northern end of the village N. of the old Crossag Bridge ; and in the road at *Ballatarrant* and *Ballavoddan*, W. of *Awin Ruy*.

In the bed of the Silverburn, at the weir 50 yards N. of the Crossag, there is a good exposure of steeply-tilted limestone which Cumming believed to occur on the course of a fault striking N. 10° W. mag.¹ On the W. side of the river 150 yards N.N.W. of this exposure the limestone has been quarried. The outcrops in the higher portion of the valley and in the bed of Awin Ruy, and also that in the bank W. of Rushen Abbey have already been described (p. 197).

OF THE
SILVERBURN.

West of the Silverburn, the principal and indeed almost the only exposures are in the large quarries around Ballahot. The first of these is on the north side of the mainroad leading from Ballasalla to Arbory, on the rise out of the Silverburn valley ; the section showed (in 1893) fifty to sixty feet of dark flaggy limestone with shale partings, containing the usual fossils of the lower division, under a capping of eight to ten feet of red boulder-clay.

The largest quarries of the district are those less than half a mile farther west, on the western side of the Castletown and Foxdale highroad between Ballahot and the cross-roads. They show irregular drift 3 to 20 feet thick on 20 or 30 feet of dark flaggy limestone with lumpy bedding-planes, in courses from 1½ to 4 feet in thickness with shale partings, dipping mainly at about 6° towards S.S.W. The surface of the limestone is in places decomposed into 'umber,' and the same kind of weathering extends downward along the joints. The bottom of the quarries is below water-level, and is kept dry by pumping, partly by steam and partly by wind-power, the average annual discharge being estimated by the proprietor at about twenty-six million gallons.

Between these sections and the boundary-fault no further exposure is now visible to the northward of the Arbory road, though the top of the limestone has probably at one time been excavated in the shallow depression, 700 yards north of Booilevane, at the place marked *Umbur Pit* on the six-inch map. The soil in the field to the westward of this place is full of fragments of decomposed limestone, and the till in the gutter above *Umbur Pit* is full of limestone-rubble, which gives place to red conglomerate-rubble north of Billown farmstead, and then to slate (see p. 196).

In the absence of further evidence, the boundary adopted on the map for the limestone in this quarter has been based on the average direction of the boundary-fault where seen at Port St. Mary, Kentraugh and Athol Bridge ; and is practically identical with that of Cumming's map.² I was informed

¹ "Isle of Man," p. 44.

² Q.J.G.S., vol. ii., pl. xv., and "Isle of Man," Plate at end of vol.

however, that a well sunk seventy years ago behind the house at Ballamaddrell reached limestone after passing through 42 feet of clay, this place being one-third of a mile N.N.E. of Arbory, and half a mile beyond the boundary of the limestone as shown on the map. As slate is exposed immediately north of Arbory (Ballabeg), and again north of Billown (p. 196), the presence of limestone so far to the N.W. as Ballamaddrell could only be explained by trough-like cross-faulting. The drift in this quarter, especially towards its base, is full of limestone boulders, and the report that the well reached the limestone rock may have been based on this circumstance. The statement has been handed down verbally for two generations and is scarcely sufficient grounds for the conjectural mapping which its acceptance would necessitate. It may nevertheless be pointed out that the transverse fault exposed on the shore between Balladoole and Strandhall (p. 204) would, if prolonged, intersect the main fault in the vicinity of Arbory and would have the effect of letting down the limestone to the eastward.

South of the Arbory and Ballasalla road, the rock exposures are few until we reach the vicinity of the coast. It is said that on *Skybright Hill*, immediately to the westward of St. Lupus's (Malew) Church, the limestone lies only two feet beneath the surface, a statement supported by the abundance of limestone fragments in the soil. Like Creggans Hill, the aspect of this ridge is that of a drift-feature, and as such it was regarded by Cumming;¹ but if the limestone occur as stated, the drift must be only a thin veneer on a hillock of rock.

Dr. J. Clague of Castletown informed us that he remembered a small limestone quarry, now quite obliterated, in a field about a quarter of a mile S.W. of Ballanorris. On the rising ground north-west of Ballakeigan farm, a little over half a mile S.S.E. of Ballanorris, the drift is very thin, and the soil full of limestone-fragments; and dark limestone in place is exposed and has probably been quarried under the fence at the north-eastern corner of the field, 300 yards W.N.W. of the farm-buildings. This is another example of a drumlin-like mound proving on examination to be a solid feature, and shows that the unevenness of the surface in this area is by no means due solely to the drift-deposits.³

South of Ballakeigan, dark fossiliferous limestone dipping nearly west is visible in the bed of the little stream draining to Poolvash, a few yards above, and 100 and 250 yards below *Maddrell's Bridge*, the crossing-place of the Castletown high road. A boss of cherty limestone may also be seen in the adjoining field about 100 yards south of the last of these exposures. To the southward, between Knockrushen and Poolvash, and to the westward on the hummocky ground between the high road and the coast at Balladoole, there are numerous outcrops of massive pale limestone, apparently belonging to the Upper or Poolvash division (see p. 216). Rock of similar character is exposed in an old quarry in a field 150 yards north of the highroad at *Cross Welkin Hill* near Balladoole; but the soil at the foot of the hill is full of fragments of dark flaggy limestone, so that the junction of the divisions may lie between these points. A few hundred yards farther west, at 150 to 350 yards from the coast, dark limestone dolomitized in places is visible in both banks of the stream which reaches the sea at Strandhall. If the Balladoole fault (Fig. 53) were prolonged in a straight line, this exposure would lie to its eastward or down-thrown side, and ought therefore to reveal the Upper Limestone; whereas it presents the characters of the Lower Limestone, so that it is probable the fault has an easterly curve and passes to the east of this section.

Between the last-mentioned stream and the boundary-fault no actual outcrop of the limestone was seen, but the soil in the fields adjacent to the by-road leading from *Strandhall* to Cronkmooar, from 350 to 750 yards north of the shore, contains fragments of dark flaggy limestone in such abundance that the rock must lie near the surface, and has therefore been indicated on the map.

¹ My informant being Mr. T. Maddrell of Ballamaddrell.

² "Isle of Man," p. 54.

³ Compare Cumming, "Isle of Man," pp. 52 to 57.

The Poolvash or Upper Limestone.

This division as recognised by Cumming occurs in a series of remarkable exposures on the shore between the Balladoole fault and the outcrop of the Volcanic Series at Poyll Vaaish, a space of about half a mile; and extends inland for about the same distance, in a strip running roughly parallel to the coast from Balladoole to the vicinity of the western shore of Castletown Bay.

Before entering upon the description of the very curious and exceptional stratigraphical relations of this limestone, we will take into consideration the general account given by Cumming in the following passages.

"The Upper Carboniferous limestone or Yoredale series, is only found at Poolvash to the west of the burn which comes down from Balladoole. It is of a light colour, made up almost entirely of fossils, of which nearly 200 varieties have been collected within the area of an acre. It has, comparatively speaking, few species (not more than 30 in 200) in common with the lower dark limestone series, and seems to have been originated under very different conditions: the sea had evidently become shallower. Its characteristic fossils are *Orthis resupinata*, *Terebratula excavata*, *Productus striatus*, and *Goniatites crenistria*, all very abundant. It occupies a very small space of hardly more than half a mile in extent, rising up into a low hill to the west of Balladoole House, and has been much dislocated and altered by the intrusion of trap dykes on the sea-shore south of Balladoole. Owing to these dislocations and to the covering of boulder clay, its passage into the lower limestone is hardly to be made out."

The above sentences contain Cumming's latest description of the deposit.¹ In his earlier writings the following additional details are given.

"The best place for tracing the connexion" [with the lower limestone] "seems to be at the edge of the fault at Poolvash, about 300 yards westward of the road running from Balladoole to the sea-shore, where some dark beds, which look like the commencement of the lower limestone, are brought up; but as not more than four or five feet appear, the few fossils contained in them are hardly sufficient to establish their identity. There can, however, be little doubt that a great and almost sudden change took place in the physical condition of the basin in the midst of the period of the deposition of the limestone strata, almost every species of mountain limestone fossils being crowded within a thickness of not more than sixty feet of limestone, and in an area of scarcely a mile across. Even here, however, we may remark, that the various beds of the series have individually their own more characteristic fossils. Thus I have found *Nautilus oxystoma* in the lower Poolvash beds alone, and the same species (but of much larger size) in the lowest dark limestone of Ballahot. The beds next above seem characterized by a *Natica*

¹ From "Guide to the Isle of Man" (1861), p. 161.

and by *Cyathophyllum busultiforme*. In the next we have *Orthis resupinata* and *Goniatites crenistria*, extremely common and later still, *Nautilus sulcutus*. Some of these fossils range more or less through the whole series. The Orthoceratites are more common in the middle period, and so also is *Terebratula excavata*. Somewhat earlier we have *Producta anomala*, and a little crustacean, named by De Koninck *Cytherina Phillipsiana*, pervades both the earlier and middle beds. In the upper portion the larger corals disappear and give place to *Fenestella*, while in that part even the Encrinites are not abundant in proportion to other fossils."¹

In discussing these facts in his larger work² he remarks:—"The light-coloured limestones . . . seem separately divisible into (so to speak) zones of life; and thus we see, even within the very limited area of this basin, that, as in the present day, so also in the palæozoic period, there were certain ranges of depth within which each animated species was confined, and that whenever, from any cause the sea-bottom was elevated or depressed, certain species died out, and others came in to take their place."

These statements as to the distinctiveness of the fauna of the Poolvash Limestone are of especial value for their bearing upon its stratigraphical relationship to the other divisions. The examination of a selection of the fossils by the palæontologists of the Survey in the preparation of the list given on p. 256 has somewhat modified, but on the whole supported, Cumming's results.

The curious mode of occurrence of the pale limestone on the coast westward of Poolvash did not fail to attract the attention of Macculloch, who noted that pale grey or impure white unstratified limestone, often crystalline and refractory like primary limestone, "which accompanies the regular beds is found irregularly interspersed in detached masses throughout the whole calcareous tract of which it forms a part. It is neither placed above, nor, as might more naturally be expected, below the strata, but is irregularly intermixed with them, forming a portion of the common deposit." . . . "In almost every instance, its superior hardness and the greater resistance it offers to the sea and weather, cause it to project in rough masses, often many feet in height, above the surrounding stratified rock. . . . In some instances it decomposes by weathering into round honeycombed cavities separated by irregular ridges; resembling that limestone which occurs at Broadford and at Kilbride in Skye." He then goes on to discuss at considerable length the relations of the limestones to each other, with the object of proving that the unstratified limestone need not be "primary."³

¹ Quart. Journ. Geol. Soc., vol. ii., p. 322.

² "Isle of Man," p. 241.

³ "Western Isles," vol. ii., pp. 555-566, and vol. iii., pl. xxvii.

Henslow more briefly described the phenomena and them by an excellent section.¹ In discussing [which sometimes takes place in the limestone, when becomes reddish-brown and the texture crystalline tion] . . . slightly visible in Castletown Bay, but to the south [westward] of Poolvash," he adds—"forms a separate belt in the latter case or is merely a of the regularly stratified limestone is not so apparent spot, however, near the black marble quarries at P or three eminences occur of this nature rising through strata, which are wrapped round and abut against the perspicuous manner, the change being extremely unstratified portion having a rugged appearance and with fossils, the surrounding strata thin, slaty, and containing a trace of any."

Cumming seems to have regarded the features mentioned in the above descriptions as part of the general discolouration due to the intrusion of the olivine-dolerite which he generally assigned greater importance than has been acknowledged; and intentionally eschewed any discussion of the unstratified bosses. "Westward of the dolerite," he remarks, "the trappaceous deposits [i.e., Volcanic] do not appear, and the shore is so much intersected with dykes and the rocks are so much altered, as to prevent all of that neighbourhood."² In another place he says it is impossible to make out any order in the beds, but is generally evident that in proceeding north-westward the strata are descending again into the lower series."³

No later discussion of the peculiarities of this limestone has been attempted, until the present writer gave a description of the exposures in the Handbook prepared for the Liverpool meeting of the British Association in 1896, in which he suggested that the hummocks of pale limestone were "Knoll-reefs," like "the bosses described by Mr. R. H. Stoddart in the Carboniferous Limestone of the Skipton district, Yorkshire."

Description of Sections.

COAST
AT POOL-
VASH.

Starting from the north-western part of the exposed Balladoole fault, we pass from the dark flaggy Limestone to the westward of the fault to a confused mass veined in every direction with calcite and quartz. The line of the dislocation forms a shallow channel a few feet wide on the foreshore, more or less filled with shingle, but here and there traces of a small decomposed dyke of dolerite among the fault-stuff. To the eastward for a short distance a shelving bank of shingle, probably in part composed of the Raised Beach, extends above high-water mark.

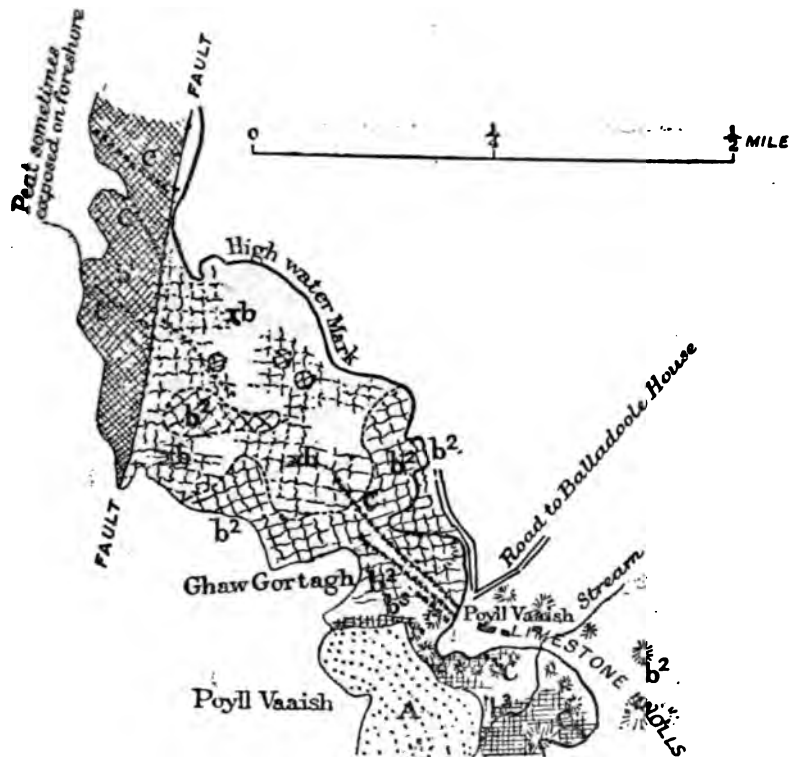
¹ Trans. Geol. Soc., vol. v., pp. 492-3, and pl. 35, fig. 1.

² Quart. Journ. Geol. Soc., vol. ii., p. 333.

³ "Isle of Man" p. 136.

is no cliff. The shore, a quarter of a mile broad at low water, is composed of low platforms of limestone, sprinkled over with shingle and boulders, and broken up by wide basin-like depressions in which the accumulation of shingle hides the rock. Some of these depressions are not drained at low tide, and in the

FIG. 53. *Sketch-map of foreshore north-west from Poyll Vaaish. (Reduced from 25-inch field map.)*



- A. Volcanic Ash.
- b². *Posidonomya*-beds (limestone-shale).
- b². Poolvash Limestone, forming knolls.
- b¹. Lower Limestone.
- xb. Dolomitized and brecciated limestone (with unaltered patches of b²).
- c. Olivine-dolerite dykes.

summer they become choked with decomposing seaweed which renders this little area a most uninviting portion of the otherwise charming coast. Immediately to the eastward of the fault-channel, where rock is visible it consists of brown dolomite which appears to have been shattered into small fragments and recemented by the segregation of white thread-like veins of quartz and calcite which make a delicate lace-like network on the weathered surfaces. This structure accompanies

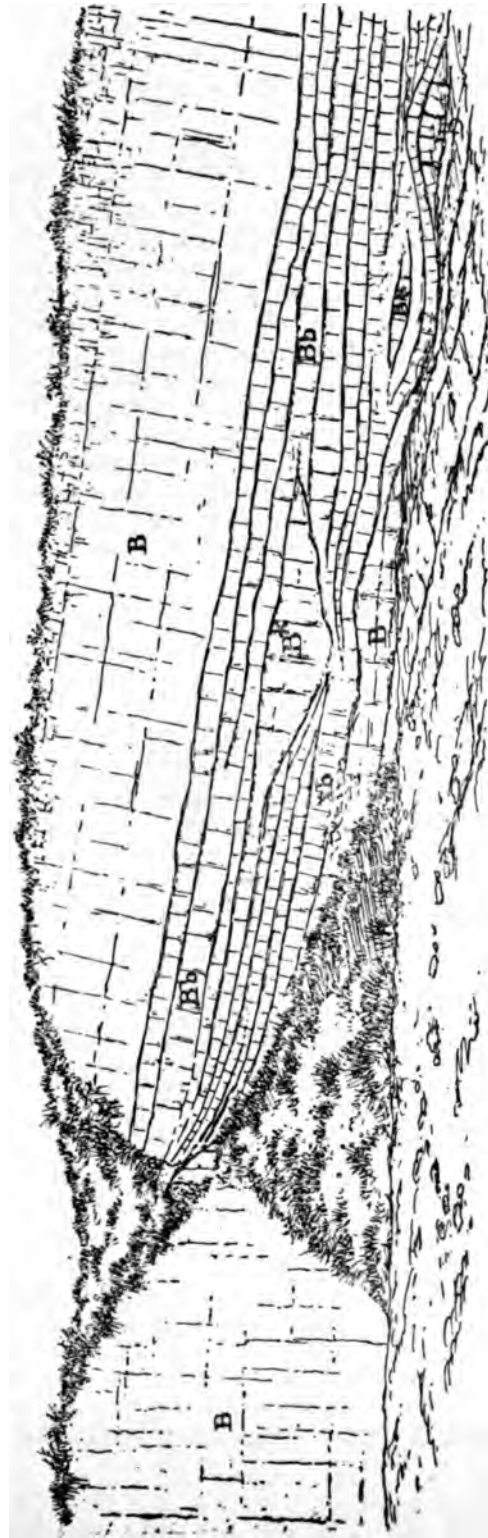
the fault down to low water and occurs again, in places, among the dolomitized rock 150 to 200 yards east.

The limestone for 20 or 30 yards to the eastward of the fault is completely dolomitized and defossilized; but at that distance, patches of less altered rock make their appearance towards low-water, forming islands in the altered mass; and a few yards farther E. we reach a larger unaltered tract of massive pale limestone of the Poolvash type, containing many fossils. The same features are repeated at high-water mark, but as the shingly hollow of *Poyll Ritchie* intervenes, the first actual exposure of fossiliferous rock which has been noted lies over 100 yards E. of the fault. By a rapid increase in the size of the undolomitized or only slightly dolomitized patches, we pass eastward out of the zone of conspicuous alteration in the vicinity of *Ghaw Gortagh*, about 500 yards E. of the fault, where the dolomitization disappears rather suddenly, but without there being sufficient evidence to show whether it is arrested at a definite plane of bedding or faulting, or whether, as appears probable, it dies out laterally among the beds. The foregoing reduction from the working field map on the 25-inch scale will illustrate these features (Fig. 53).

The general arrangement of the unaltered patches in the tract above described seems to imply that they have formed knolls of massive pale limestone surrounded, like those farther east, by darker flaggy beds; and that while the flaggy beds have undergone complete dolomitization, the less readily altered knolls have preserved an undolomitized core. Traces of flaggy bedding may still be detected in a few places towards the edges of the dolomitized masses, and afford evidence in favour of the supposition; but the absence of any indication of shale-partings among the altered rock tells somewhat against it. As a rule no dip whatever can be discovered in this area, but there is a faint suggestion of a southward or S.S.W. dip in the larger unaltered tract at *Skeir Lea* at dead low-water, 150 yards N.W. of *Ghaw Gortagh*. From the gradual fading of the dolomitization in this quarter it seems probable that the alteration has not extended seaward much beyond low-water mark. Two small parallel dykes of olivine-dolerite, respectively 2 feet and 1½ feet thick, may with difficulty be traced at intervals in the altered limestone of the obscure ground from 50 to 100 yards S. of *Poyll Ritchie*; and are probably continuous with the corresponding though broader dykes at *Ghaw Gortagh*. Cumming, as we have seen, sought to connect the dolomitization of the limestone with the intrusion of these dykes¹, but for this there is no evidence.

¹ "The very great alteration which has taken place in the [dolomitized] limestone here would seem to indicate that this was the grand focus of disturbance at the period of the trap-dykes, and this is further confirmed by the circumstance that the majority of the dykes which stretch over the area seem to converge towards this locality as a centre." "Isle of Man," p. 136.

FIG. 54. *Cliff-section of Carboniferous Limestone, 400 yards north-west of Poyll Vaish.*
Height 16 feet.



- B. Massive pale limestone ; bedding obscure, fossils abundant.
- B*. Lenticles of limestone similar to B.
- Bb. Dark flaggy limestone with shaly partings ; irregularly bedded in vicinity of B* : fossils abundant.
- xb. Limestone breccia.

From the deep basin-like hollow on the shore due north of Ghaw Gortagh there gushes out, during ebb-tide, a strong spring of salt water (marked on the 6-inch map, Sheet 16), no doubt due, as Cumming suggests, to the existence of underground cavities which are filled by the sea at high tide.

To the eastward of this place the shore is occupied by huge cuboidal masses of pale crystalline limestone, often standing up above high-water mark with vertical walls formed by joint-planes, and thus constituting small islands when the tide is at full. In some places this rock is devoid of fossils, while in others it is crowded with well-preserved organisms, uncrushed and in excellent preservation, the interior of the brachiopod shells being sometimes hollow and lined with calcite crystals. Towards high-water mark, darker flaggy limestones with shale-partings enfold these masses and in places appear to dip beneath them, apparently occurring as huge lenticles among the massive beds. The shore at this spot terminates in a low cliff, which shows the preceding section under the cottage 230 yards N. W. of the road from Balladoole House (Fig. 54).

One hundred and fifty yards S. of this section, opposite another cottage, the cliff has weathered down into a grassy slope, with a protruding crag on its brow which is extremely rich in fossils. This is perhaps the best place for collecting the Poolvash fauna though the bare rock-platform jutting out from the cliff-line 100 yards nearer Poolvash is also very prolific.

These platforms on the upper surface of the pale limestone-knolls are probably the remains of the shore-terrace of the Raised Beach period. As noticed by Macculloch, they are curiously weathered into a honeycomb of small pits, several inches to a foot or more in depth, separated by knife-edged ridges.

Continuing eastward towards Poolvash, we seem to reach a somewhat higher horizon in the succession, and find that the pale unstratified masses have been almost entombed and overlapped by the flaggy dark limestones, though here and there the crest of a knoll rises abruptly, sometimes with a steep cliff-like margin, above the encircling beds. Near high-water mark on the southern side of the little bay south of Poyllvaish farmstead, the final stages are seen, in which the flaggy beds, constituting part of the "Posidonia Schist" of Cumming, sweep in a succession of smooth domes over the crests of the knolls, so that only where the flags are broken away is the inner core of massive limestone visible.

It is an important feature of these exposures that in juxtaposition with the knolls there is usually a band of limestone-breccia, consisting of subangular and rounded fragments of pulish limestone in a dark calcareous paste. This is best seen when the rock is wet, as when dry the bruised and battered surface produced by recent wave-action masks the distinction

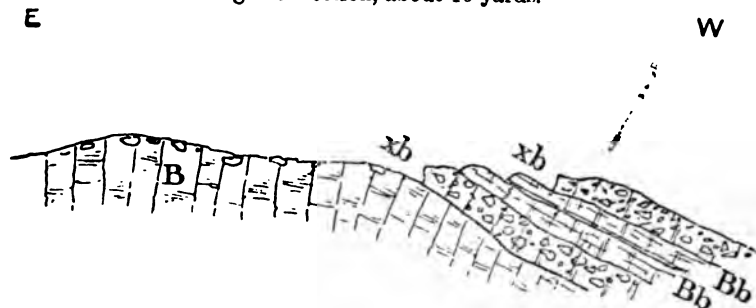
between matrix and inclusions. No rock except limestone has been observed among the "pebbles."

The breccia is usually developed only upon the steeper flanks of the knolls and in the flaggy layer immediately overlying their summits: but in a few places on the shore S.W. of Poyllvaish farm, lenticles of the breccia occur among the limestone-flags in the intervals between the knolls. Fossils are often abundant in the breccia, particularly small compound corals and fragments of encrinites. Similar fossils occur plentifully in the enfolding flaggy beds, and corals are much more conspicuous in these dark limestones than in the massive pale rock of the knolls.

The following section on the shore of Poolvash 200 yards south of the farm-house illustrates the mode of occurrence of the breccia.

FIG. 55. *Top of boss of pale limestone, on beach west of ruins of "Chapel and Burial Ground" (6-inch map, Sheet 16) Poyll Vaaish.*

Length of section, about 10 yards.



B. Massive pale limestone (Poolvash Limestone); outer layer full of fossils (encrinites, corals, and shells) with some round pebble-like lumps of limestone up to 6 inches in diameter.

Bb. Dark limestone-flags with shale partings (Posidonomya Beds) mantling around the boss of B.

xb. Bands of limestone-conglomerate one to two feet thick, made up of more or less rounded fragments of limestone up to one foot diameter; many fossils (corals, encrinites, etc.).

The knoll-structure is most beautifully exhibited, though not perhaps under the best conditions for study, on the northern foreshore of Poolvash inlet, opposite the farmstead. At this place, as indicated by the ornamentation on the 6-inch and 25-inch Ordnance maps, isolated masses of pale limestone, from 10 to 15 feet in diameter and from 5 to 15 feet in height, form an irregular chain running with a slight curve nearly east and west (see plan, Fig. 53). This chain is terminated abruptly westward by the overlap of the volcanic ash occupying the lower part of the shore; but is prolonged eastward inland in the hillock of

Cronk-y-Watch immediately north of the farm-house, and in bosses partly revealed in the field 100 yards farther east. A group of olivine-dolerite dykes (see plan, Fig. 53; also table on p. 331) traverses the shore between Poolvash and Ghaw Gortagh, cutting through knolls and flaggy beds alike; it is clear that these are as little responsible for the arrangement of the limestone at this place as for its alteration north of Ghaw Gortagh.

The most southerly exposure of the limestone bosses on the coast occurs just above high-water mark on the southern side of Poolvash inlet, only 30 or 40 yards south of the section figured above (Fig. 55). The *Posidonomya* or Black Marble beds then completely overlap them to the westward and southward, occupying a little strip on the upper part of the shore while the lower part is composed of the overlying Volcanic Ash which is continuous southward from Ghaw Gortagh to Scarlet Point.

Cumming was inclined to think that the confused and brecciated mass of limestone, which is apparently overthrust upon the Lower Limestones at the edge of the Volcanic rocks at Scarlet, might correspond to the limestone of the Poolvash knolls, but this correlation is doubtful (see p. 244).

Inland Extension of the Poolvash Limestone.

Within 150 yards of the coast to the north-westward of Poyllvaish farm, scattered hummocks of bare limestone rise above the drift-gravel; similar outcrops are seen in two or three places around the outbuildings of BALLADOOLE Balladoole House; and a bare ridge of limestone forms the rough ground on which stand the traces of the old chapel and burial ground, *Keeill Vael*, 200 yards north-west of the last-named house. The ridge extends across the road leading to the house; and the same rock is exposed in small bosses in the fields on the eastern side of the road for 200 to 300 yards farther north. Similar exposures occur along the western and northern fences of the field north of that in which *Keeill Vael* stands, and extend thence north-westward along the fences of the adjoining fields to within 120 yards of the Castletown highroad. The exposure in an old quarry 150 yards north of the same road, on *Cross Welkin Hill*, has been previously mentioned. All these outcrops are of pale greyish crystalline limestone of the Poolvash type, occasionally but not usually fossiliferous; and from their mode of occurrence it is probable that they constitute a series of similar knolls to those seen on the shore.

OF
VASH. Another chain of exposures extends south-eastward from Poolvash towards the western shore of Castletown Bay south of Knock Rushen, running parallel to and not far distant from the inland margin of the Volcanic rocks. The outcrops take the form of low bosses of pale massive limestone in the cultivated fields, separated from each other by stretches of drift-gravel, each probably indicating the crest of a separate knoll. One of these bosses, on the southern side of the little stream at Poolvash, 120 yards inland, shows a patch of dolomitized limestone on its north-east flank; another, in a similar position 200 yards farther to N.E., has some darker limestone and shale associated with the massive rock, like the knolls on the shore. Several other bosses occur in the fields bordering the Poolvash inlet, from 200 to 300 yards N.E. and N.E.E. and again 500 yards due east of the "Black Marble" quarry. These and other similar outcrops have necessarily been indicated on the published drift-map as if continuous with each other, the scale not permitting the individual bosses to be shown.

The next exposures are about $\frac{1}{4}$ mile farther south and 370 yards south-east of the earthwork marked **Fort** on the one-inch map, extending east and west for about 250 yards, to within 130 yards of high-water mark. In these, pale massive limestone rich in fossils appears to project in a narrow tongue into the margin of the Volcanic Ash (see p. 236). To the southward of the above, no actual exposures were seen; but from the shape of the ground and the character of the soil there appears to be a thinly covered boss in a field 550 yards W. 5 S. of Scarlet House. Eastward, massive bluish limestone, weathering paler, crops up in the uneven ground 60 yards north-west of the farmhouse rather over $\frac{1}{4}$ mile north-west of Scarlet House.

The last exposure to be described is that to which reference has already been made, on the hillock of *Knock Rushen*, within 150 yards of the shore immediately south of Castletown, where massive grey limestone containing many fossils is seen around the outbuildings of Knockrushen House, and in the field to the north-westward. In one part of this outcrop a south-easterly dip was observed, which if continued would carry the bed beneath the Lower Limestone of the coast-section; so that it is somewhat doubtful whether we are justified in including the exposure in the Upper Limestone. It may be merely a bleached and weathered outcrop of one of the thicker beds of the Lower Limestone; Cumming, in his earliest paper, seems however to have recognised it as belonging to the upper division, though the following passage is the only reference to it which he makes:—"How far inland the Poolvash limestones extend, I have not as yet seen; the outcrop is seen at Knockrushen at the south-eastern side of the basin, and they must have been denuded from the whole of Castletown Bay, if indeed they ever extended in that direction."¹ His later writings contain no mention of the locality, and moreover limit the Upper Limestone to the area west of the stream at Poolvash, thus excluding all the inland exposures described above, except those around Balladoole (see extract quoted on p. 208). There seems no likelihood of a fault of any magnitude coming between the Lower Limestone of the shore and the Knockrushen outcrop, and its correlation with the upper division, if it could be established, would afford better evidence than is elsewhere obtainable for the relationship of the two divisions, since the massive limestone of this place must be in direct contact with the undoubted Lower Limestone of the shore of Castletown Bay. If the same relationship be continuous to Poolvash, we might reasonably consider the dark flaggy limestone and shale there associated with the "knolls" as the direct upward continuation of the Lower Limestones, slightly modified by changed conditions. But Cumming apparently considered these Poolvash flaggy beds as forming part of his "Posidonia Schist," though it is by no means clear how much he intended to include in that division. A careful investigation of the fossil contents of the Knockrushen outcrop and a comparison of them with those of the Poolvash Limestone on the one hand, and of the Lower Limestone on the other, might serve to elucidate this matter.

The evidence as to relations of the Poolvash Limestone to the *Posidonomya* Beds and of both to the Volcanic Ash, which will be given in the subsequent pages, is essential to the discussion of the origin of the "knoll structures;" and we will therefore postpone the question until that evidence has been stated (see p. 248.)

Posidonomya Beds.

Cumming's latest account of this unsatisfactory and difficult division is as follows:²—"Posidonia schist was the name given by the author, in a paper read at the meeting of the British

¹ Quart. Journ. Geol. Soc., vol. ii., p. 334.

² "Guide Book," pp. 161-2.

Association in 1845, to a remarkable formation of black schistose beds occurring at Poolvash . . . and locally known under the name of Poolvash black marble. The name was given from the occurrence therein of the characteristic fossil, *Posidonia Becheri*. It is used economically to some extent for tombstones, chimney-pieces and flagging, the steps of St. Paul's Cathedral having been obtained from these quarries and presented by Bishop Wilson."

"After the deposit of the beds of Upper Scar limestone [*Poolvash Limestone*¹] violent convulsions, accompanied with the protrusion of trap and outpourings of volcanic ash, appear to have affected this area in a remarkable manner, crumpling up the strata into folds . . . and forming a number of troughs or smaller basins and hummocks in the limestone. These phenomena may be seen more particularly in Poolvash Bay, between Scarlet Head [= ? *Close-ny-Chollagh Point*, of 6-inch Ordnance Map] and the mouth of the stream from Balladoole. At periods of greater volcanic quiescence were formed the beds of *Posidonia* schist, in a shallow sea or estuary into which the rivers were bringing down the black mud of which the schist is composed. The proximity of land appears from the singular fact that in these beds of *Posidonia* schist we meet with plants of the coal strata, *Adiantum*, *Pecopteris*, *Sphenopteris*, *Lepidostrobus ornatus*, and *Calamites*. We meet at the same time with truly marine organisms, such as *Goniatites* and *Orthocerata*, . . .

"The *Posidonia* schist is sometimes found overlapping the felspathic ash, which had filled up the hollows, and resting directly upon the limestone. After a period of quiescence the volcanic action seems to have set in again, accompanied with violence and partial breaking up of the previously formed beds, producing a breccia in which we meet with fragments of the *Posidonia* schist, somewhat altered, and presenting the appearance of chert, and then a more quiet deposit of ashes, and the formation of other beds of the black carbonaceous mud; but on account of the dislocation of the strata, the exact sequence cannot readily be made out.

"It is extremely interesting to notice the formation of volcanic ash in the midst of the carboniferous strata, containing carboniferous fossils, and to compare it with similar formation in Silurian times."

In his earlier paper, Cumming gives further details regarding the deposit, describing it² as "a schist or plate, in some places ten feet thick, in others not so many inches. It is characterized by an abundance of very beautiful and perfect *Posidonia*, by several cephalopodous shells, not occurring elsewhere in the basin, and in one place by several varieties of Ferns, the nearest approach here to the Coal-measures. All the shales abound in iron-pyrites;

¹ The words in brackets are not in the original.

² Quart. Journ. Geol. Soc., vol. ii., p. 323

and in one spot we find, a little to the east of a stream running from Balladoole into the sea, and parallel with a trap-dike, several extremely beautiful fossils of this material, consisting mostly of *Goniatites* and *Orthoceratites*."

In another place¹ he adds the information that "the ferns and *Favosites Gothlandica* may be met with in a hollow near three dykes, about 300 yards westward of the Balladoole stream" (see plan, Fig. 53).

The last quotation is important inasmuch as it shows that Cumming included the flaggy beds surrounding the "knolls" to the westward of Poyllvaish in the "Posidonia Schist," though elsewhere he seems to confine the term to the "black marble" deposit of the eastern side of the inlet. But with this division as with the Poolvash Limestone, he avoids, and indeed deprecates, any attempt to define its limits accurately, aptly comparing the present arrangement of the whole Carboniferous series in this quarter to the frozen surface of a fresh-water lough just accessible to the sea, in which successive layers of ice have been partially broken up and tilted by the influence of the tide and partially overlapped by new ice.²

The only later published account is that of Mr. John Horne, whose brief notice of the deposit contains the following passages³:—

"Lithologically, they ["The Poolvash Black Marble Beds"] are distinct from the underlying groups, and imply a change in the physical conditions which existed during the time of their formation. In the quarry south of Poolvash, where they have long been worked, the beds consist of black shales and black calcareous flagstones, varying in thickness from 6 to 18 inches. They dip nearly west, but north and south of the quarry on the shore they roll about. . . . On the shore at the north of the Poolvash Burn they are interstratified with thin white limestones, which resemble the limestones of the underlying group."

In discussing Cumming's statement that the Posidonia schist did not appear to have any exact equivalent in the British Islands, Mr. Horne remarks:—"From the manner in which the black shales and flags are interbedded with bands of white limestone, it occurred to me that they really belonged to the close of the white limestone group, though implying different physical conditions. If it be true, as Cumming infers from the nature of the fauna, that the white limestones were deposited in shallow water, then it might quite well have happened that the change from one set of conditions to the other was a gradual one. But, further, the fact that the black marble beds, which are in all probability estuarine, being interstratified with the white limestones, seems to point out an

¹ "Isle of Man," p. 359.

² *Ibid.*, pp. 134-5.

³ Trans. Edinburgh Geol. Soc., vol. ii., pt. iii. (1874), pp. 330. 331.

alternation of the conditions under which they were deposited. Slight elevations and depressions no doubt intervened."

"Mr. R. Etheridge, Jun., F.G.S., has kindly furnished me with the following note on the fossils found in these beds":—

"Of the thirty-six species of animals mentioned by the Rev. J. G. Cumming as characteristic of his *Posidonia* schist, we may eliminate three species as undetermined, two of doubtful determination, and seven new species created by the author himself, and which from a stratigraphical point of view prove nothing. This leaves twenty-four good species, of which twenty-two are characteristic carboniferous limestone forms. The two remaining species, *Posidonia Becheri*, Phill. and *Posidonia literalis*, Phill., are more particularly representative of the upper limestone shales and Yoredale rocks, that group of shales, grits, and fine sandstones which in central England intervene between the true Carboniferous limestone and millstone grit. It is to the horizon of the upper limestone shales that the *Posidonia* schist is probably referable. Some few of the above twenty-two limestone species have been met with in the Coal Measures, but only under exceptional cases and conditions."

Description of the Sections.

The *Posidonomya* Beds, as described in the above quotations, cannot be recognised anywhere excepting in the limited coast-exposure at Poolvash. Here they are typically developed only in a small patch about 200 yards long by 150 yards or less in width, on the upper part of the shore immediately to the northward of the **Fort**. They are best seen in the "Black Marble" quarry,¹ now no longer worked, 75 yards N. of the **Fort**, where they are traversed by one of the larger olivine-dolerite dykes. This dyke, though in one place only 9 feet, is for the most part from 15 to 18 feet wide, and in making an elbow on the shore just outside the quarry, expands to a width of 39 feet; in its north-westward course it crosses the junction of the *Posidonomya* beds with the Volcanic Ash, and is prolonged among the Ash to near low-water mark, where it splits into several branches. In the quarry its effect upon the "black marble" is to render the deposit splintery and to destroy the flaggy character for a space of 7 to 9 feet from the contact on its northern side.

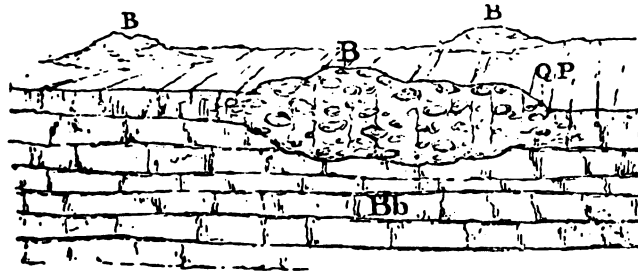
The quarry shows 24 feet of the *Posidonomya* Beds consisting of smooth dark regular limestone-courses, from 4 inches to 2 feet in thickness, with partings of black shale ranging from 2 to 6 inches thick, these partings being thickest in the upper

¹ In most Manx topographical works one finds the statement that the steps of St. Paul's Cathedral were obtained from this quarry. Cumming notes that this event took place in the days of Bishop Wilson, *i.e.*, early 18th century. ("Isle of Man," p. 132.) The rock is not particularly durable, and the steps probably perished long ago; at any rate there are no steps of this character now in existence outside the cathedral.

part of the beds. A capping of coarse gravelly and clayey drift 6 to 12 feet thick, resting on a well-glaciated rock-surface, completes the section. The bottom of the quarry, being below high-water mark, is generally flooded; it does not seem to have reached the base of the flags. A greater thickness of the Posidonomya beds is revealed in this section than in any other exposure, and indeed it is greater than one would have estimated from the study of the outcrop on the shore.

As we have already seen, northward of the little stream in Poolvash inlet, the "knolls" of massive limestone approach the boundary of the Volcanic Ash, and the dark flags and shales which represent the Posidonomya Beds are confined to the flanks of the knolls and the hollows between them. Westward, the extension of the flaggy beds inland must be cut off within 150 yards of the low cliff by the chain of knolls previously

FIG. 56. *Section on shore slightly below high-water mark opposite Poyll Vaaish Quarry. Height about 3 feet.*



Bb. Dark limestone-flags with shale partings (Posidonomya Beds).

B. Boss of paler limestone, 6 feet diameter and $1\frac{1}{2}$ feet thick, crowded with shells, principally *Productus*. A quartz-pebble, $1\frac{1}{2}$ inches in diameter, was embedded in it at Q.P.

BB. Bosses similar to B protruding above the same bedding-plane; not in the line of the section.

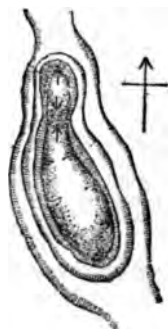
described; while inland southward also, the massive limestone and the Volcanic rocks are nearly, if not quite, in contact within a short distance of the coast (see p. 217).

Cumming regarded the Posidonomya Beds as having been deposited in little basins and troughs between the hillocks of Poolvash Limestone, and this of course implies that the knolls of the latter were in existence prior to the deposition of the Posidonomya Beds. The partial interbedding of the two divisions, to which Horne draws attention, would not seriously impair this explanation, since it need indicate only a certain degree of contemporaneity between them during the transition from the earlier to the later set of conditions. Indeed, on the foreshore just opposite the quarry there seems, as shown in the above figure (Fig. 56), to be direct evidence that the formation of knolls

and flaggy beds has gone on, at any rate on a small scale, simultaneously, and therefore that masses of the pale limestone may occur at different horizons in the flaggy beds.

It is, however, essential to this explanation that the knolls should be regarded as structures of original deposition; and though such has hitherto been my own opinion¹ and one which, after repeated re-examinations, I am still disinclined to relinquish, a powerful argument has recently been put forward by Mr. J. E. Marr² to show that somewhat similar phenomena in the Carboniferous Limestone of north-western Yorkshire have been caused by complicated folding and earth-movement. Hence it becomes important that we should closely investigate the indications of disturbance in the rocks in question; and while I still fail to understand how any combination of movement can have produced the Manx knoll-structure, it is undoubtedly the fact that intricate crumpling and overthrusting can be detected in this area at the junction of the Volcanic Rocks with the Posidonomya Beds.

FIG. 57. *Plan of a dome in dark limestone-flags (Posidonomya Beds) on the foreshore S.W. of Poyll Vaaish Quarry, adjacent to junction of limestone with Volcanic Ash. Length 40 yards; breadth 10 yards.*



The arrows indicate direction of dip.

Junction of the Posidonomya Beds with the Volcanic Ash.

On the shore opposite the "Black Marble" quarry the smooth flaggy Posidonomya Beds have been thrown into a succession of steep ellipsoidal domes of variable size, with quaquaversal dips, as shown in the plan of a single example given above (Fig. 57), resembling those already noticed in the Lower Limestone; and

¹ See "Outline of the Geology of the Isle of Man," British Association, Liverpool, Handbook, 1896, p. 174.

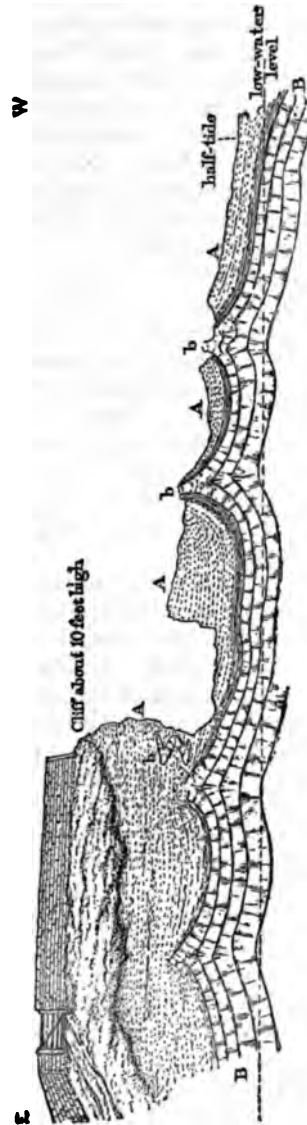
² Quart. Journ. Geol. Soc., vol. lv. (1899), pp. 327-358.

these undulations continue up to the boundary of the Volcanic Ash.

The Ash makes its appearance in the low cliff 60 to 80 yards south of the quarry, and it extends thence across the shore and

FIG. 58. Section across the foreshore on the northern side of Close ny Chollagh Point, Poolbeg; showing the rucking up of the Upper Limestone beneath the Volcanic Series. Length of section about 120 yards.

(From Quart. Journ. Geol. Soc., vol. lvi.)



- A. Volcanic ash of medium texture, with (b) contorted strips and fragments of cherty limestone.
- B. Dark flaggy limestone (Posidonomya Beds); platy, indurated and pyritous in the uppermost layer, with signs of shearing (= thrust-plane); rucked up into short domes, the crests of which are in places pinched into the ash and brecciated.

encircles the Posidonomya Beds on the westward as already described (see plan, Fig. 53). In approaching the junction, the crests of the undulations in the flaggy limestone become more acute, until where they disappear beneath the Ash they are

pinched up into sharp ridges, which when seen in ground-plan at their narrowest part resemble dykes traversing the Ash.¹ In a few places, twisted and partly brecciated shreds of limestone occur in the Ash in such a manner as to suggest that they have been stripped off from the broken crest of the undulation. In the basins between the crests there is frequently two or three inches of pyritous platy material, forming a definite parting between the Ash above and the limestone below, not possessing the characters of a passage-bed but like the mylonitized material of a thrust-plane. The surface of the limestone beneath this layer is usually indurated, cherty and pyritous, and sometimes slightly brecciated. These features are exhibited in the section shown in Fig. 58.

In following the junction northward along the shore, the indications of sliding of the Volcanic Ash over the *Posidonomya* Beds become still stronger, brightly slickensided surfaces being visible in places in the shaly limestone near the contact, while the characteristic cherty induration, pyritization and partial brecciation of the limestone floor is very pronounced. These features are well seen at the base of an upstanding crag of Ash, 70 yards N.W. of the quarry. The slickensides indicate a movement at this place toward N. 15 W., but the strike of the undulatory ridges usually lies between a few points east and a few points west of north.

On the foreshore in the vicinity of this crag, shallow quarrying on an extensive scale has been done in the uppermost or indurated portion of the limestone, the Ash having apparently been stripped off in search of this layer, which probably furnished the hardest and best of the so-called "black marble."

To the northward of this place, the Ash gradually approaches the knolls of Poolvash Limestone, proportionately reducing the space occupied by the *Posidonomya* Beds. In the middle of Poolvash inlet the exposures are poor, the shore being wet and shingly; but wherever the base of the Ash is revealed, it is seen to rest on crushed shaly material with strong indications of overthrusting. Minor planes of movement may also be detected in the Ash several feet above the junction. To the S.W. and W. of Poolvash farm, where the boundary draws nearer to high-water mark, the Ash seems originally to have abutted directly upon the knolls; but in all except one doubtful case the sea has now denuded the material from their flanks, as shown in Fig. 59.

In the doubtful case just referred to, the Ash at one point is in actual contact with a knoll of pale limestone; but this junction may possibly be due to small faults, as indicated in the plan, Fig. 60.

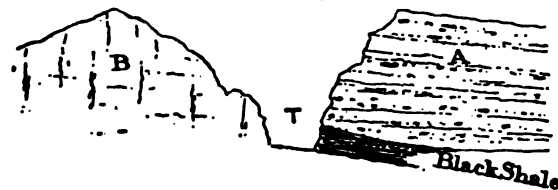
Where the junction turns westward just before sinking to low-water mark on the S. side of *Ghaw Gortagh*, the suggestion of

¹ This peculiarity was commented on by Macculloch, "Western Isles, vol. ii., p. 564.

overthrusting at the base of the Ash is strengthened by the apparent truncation of some tilted shreds of limestone which lie among the volcanic material.

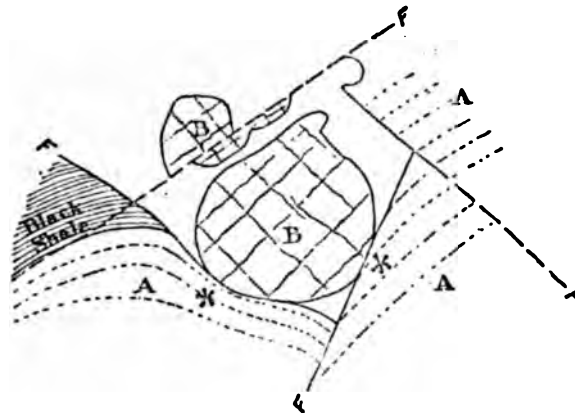
It is thus doubtful whether in any of these sections the original base of the Volcanic Series is revealed; nor can we tell for how far the Ash has been carried across the limestone by the overthrust, nor how much of the *Posidonomya* division is hidden beneath the Ash. As there is no admixture of volcanic material in the beds below the thrust-plane, it appears probable that the series is incomplete, and that higher calcareous beds showing an upward passage into the Ash may have been covered over or broken up by the displacement. We shall revert to this subject in discussing the Volcanic rocks (see p. 237), and shall afterwards review the bearing of the overthrusting upon the question of knoll-structure.

FIG. 59. *Section across gully on shore at half tide W.S.W. of Poyllraaish farmstead. Height 10 feet.*



A. Volcanic Ash, apparently overthrust upon black shale. B. Knoll of pale limestone and limestone-breccia. T. Thrust plane?

FIG. 60. *Plan of portion of shore west of Poyllraaish farmstead. Area about 20 × 20 yards.*



A. Volcanic Ash, touching limestone knoll at *, but resting on crushed black shale west of the knoll. B. Irregular knoll of pale massive limestone. F.F. Lines of dislocation (? normal or overthrust faults). The parts unshaded are hidden by beach-material.

THE CARBONIFEROUS VOLCANIC SERIES OF SCARLET.

Historical and General.

The magnificent exposure of the Carboniferous Volcanic rocks on the coast between Scarlet Point and Poyllvaish, a distance of $1\frac{1}{4}$ miles, possesses perhaps greater attractions for the geologist than any other portion of the Island, and occupies in consequence a prominent place in the literature. Berger described the eruptive material as an unstratified bed of Amygdaloid, overlying the limestone.¹ Macculloch referred to it as a breccia different from any rock with which he was acquainted, and compared it to rubbish formed on the surface by atmospheric agencies.² Henslow appears to have been the first to recognize its true character, pointing out that the greater part of the mass was not amygdaloidal trap as Berger had supposed, but trap-tuff of loose texture, traversed by dyke-like masses of amygdaloid near Scarlet, and intercalated with isolated bands of limestone in the opposite direction.³

Cumming demonstrated that the tuff must have been laid down beneath the waters of the sea, because of its close association with the limestones and the presence of marine fossils in its stratified portion.⁴ In reference to these fossils, he stated that towards the northern part of the exposure "we meet with organic remains regularly imbedded not only in the limestone, but in the trappean ash; they are chiefly corals and crinoidea,⁵ and are the newest of the palæozoic fossils occurring on the Isle of Man; they are rather abundant than otherwise, though the eye does not readily catch the particular beds in which they occur."⁶

He regarded the eruption as having accompanied or followed the production of "an extensive crack or chasm running along an axis from the Stack of Scarlet, in a direction nearly N.W. by W."⁷ His statements as to the relationship of the "Posidonia

¹ Trans. Geol. Soc., vol. ii., p. 45.

² "Western Isles," vol. ii., pp. 570-1

³ Trans. Geol. Soc., vol. v., pp. 495-6.

⁴ Quart. Journ. Geol. Soc., vol. ii., pp. 322-3.

⁵ No separate list of these fossils is given, nor does there seem to have been any attempt since Cumming's time to collect them. Fragments of encrinites are by far the commonest forms, and indeed the only kind visible to casual examination. In the Cumming collection at King Williams College, Castletown, there is a specimen of *Posidonomya* in an ashy matrix labelled "Scarlet" (see also p. 236).

"Isle of Man," p. 129.

⁷ Quart. Journ. Geol. Soc., vol. ii., p. 322.

Schist" to the Volcanic Rocks are somewhat confused, inasmuch as while they usually imply that the former underlies the latter, his coloured section¹ and certain remarks in the letter-press seem to indicate the "Posidonia Schist" as being underlain as well as overlain by volcanic rocks. The following sentences are, perhaps, intended to reconcile these inconsistencies.

"Whilst, on the one hand, the more violent eruption seems to have been but of short continuance, it is evident also that the vent (wherever it might be) was kept open, and emitted for a lengthened period volcanic ash, which was carried by the currents and deposited quietly in different parts of this area. . . . We find also a very interesting local deposit of black carbonaceous mud [i.e. the 'Posidonia schist'] going on at the same time, and mingled with the volcanic products, the prevalence of one or other in any particular locality depending, it would seem, on the relative distance of that locality from the sources of the respective ingredients there deposited At one period, indeed, the carbonaceous deposit seems to have entirely prevailed, perhaps the volcanic action entirely ceased, gathering strength for a subsequent eruption. The bed then formed has its own lithological character and fossils. It is the Posidonian schist

"This quiet and regular deposit was afterwards suddenly interrupted. The volcanic action was again exhibited with renewed violence, as at first. The lower beds of the first eruption, together with the beds of volcanic ash, of mixed trappean ash and calcareous deposits, and Posidonian schists, were contorted, broken up, reduced to a fragmentary condition, and enveloped in the outpoured deposits. There results a trapbreccia, in which the fragments of the older beds seem to have been considerably influenced by heat. The Posidonian schist has become cherty, the limestone highly crystalline, and in some cases hardly distinguishable from amygdaloid."²

The closing passages of the above extract show that the curious disturbances at the junction of the Ash with the limestone were duly recognised, and considered to be connected in some way with the volcanic outburst. With regard to the position of the orifice of the volcano, Cumming remarks:—"I have never been able to make out with certainty where the volcanic vent was that emitted the trappean materials first deposited, though I have conjectured that it was a prolonged chasm extending from the Stack of Scarlet into Poolvash Bay" (op. cit., p. 123). Cumming's knowledge of the details of the deposits was so intimate that his

¹ "Isle of Man," Section No. 2, plate vii. At first glance these sections, though published two years later, appear to be reproductions of those in his earlier paper in *Quart. Journ. Geol. Soc.*, but on comparison numerous alterations will be found in them.

² "Isle of Man," pp. 242-4.

statements, even when their meaning is at first obscure, deserve the closest attention; and his theoretical explanations will invariably be found to have been established upon a basis of accurate observation.

Quarter of a century later, Mr. Horne gave a careful account of the sections,¹ describing anew and illustrating by several woodcuts the mode of occurrence of the limestone among the ash; he concluded with Cumming that they indicated intermittent volcanic discharges; he also drew attention to the "bedded porphyrite" occurring among the ash; and suggested that the vertical junction of the volcanic rocks with the Lower Limestone at Scarlet Point might indicate "the irregular edge of an old volcanic neck."

Clifton Ward, in 1880,² agreed in all essential points with the previous observers. With regard to the basalt forming the Stack of Scarlet and its dyke-like prolongation westward, he remarks:—"There cannot be a doubt, I think, but that it represents an original line of eruption, the part nearest to the Stack being the spot where the volcanic fires first reached the surface, and where the vent became finally choked with large ejected blocks and scorïe, the basaltic lava welling up through a central fissure, and flowing over the volcanic breccia as it is seen to do upon the east side of the dyke. A little further west along the shore the greenish ashy material is less coarse, and becomes distinctly stratified, this representing the matter falling outside the vent, and becoming rudely bedded beneath the shallow sea. Just before reaching the bedded ash, other portions of the lava-flow may be seen overlying the ash, and exhibiting a very vesicular structure in bands. Nearer to Poolvash the ash is interstratified with limestone, both the grey and the black Posidonian band, so that there can be no doubt but that the eruption partook of a submarine character."

In 1889 Messrs. Dickson and Holland published some petrological and chemical notes on the Scarlet Rocks³ (see Appendix II., p. 576). Two years later Mr. B. Hobson gave an account of the petrography of the series (see petrographical notes at p. 325), accompanied by a large-scale plan and sections of the coast from Scarlet westward for half a mile. His general conclusion, as stated in the following passages, are similar to those of his predecessors. "The succession of events appears to have been as follows:—During, or after, the deposit of the Poolvash limestone a vent was opened from which fine volcanic ashes were ejected and fell into the sea, forming bedded tuff. At intervals between the eruptions the black, so-called Poolvash marble was deposited, and thus came to be interstratified with the tuff. Probably the vent became plugged up, and the violent eruption

¹ Trans. Edinburgh Geol. Soc., vol. ii., pt. iii., pp. 12–15.

² Geol. Mag., dec. ii., vol. vii., p. 5.

³ Proc. Liverpool Geol. Soc., vol. vi., pp. 128–130.

accompanying the blowing up of the plug provided the material for the agglomerate which overlies the tuff near Scarlet Point. Then lava welled forth and overspread the agglomerate. Finally the volcano became extinct, and by denudation the intrusive mass of the Stack, which I regard as a volcanic neck, was exposed."¹

There remains to be noticed the later description of the Volcanic Series given by Sir Archibald Geikie, the former Director-General of the Survey, in his "Ancient Volcanoes of Great Britain,"² based on his personal examination of the sections in 1895. With the author's permission a considerable portion of this account will be quoted verbatim. Sir Archibald Geikie's general description of the sections is as follows:—

"It may be remarked at the outset that the last outcrop of the plateau-lavas of the Solway-basin occurs only 60 miles from the south end of the Isle of Man, at the foot of the hills of Galloway, the blue outline of which can be seen from that island. The distance from the Manx volcanoes to the nearest of the puyes of Liddesdale is about 100 miles. Though the fragment which has been left of the ejections is too small to warrant any confident parallelism, there appears to be reason to believe that, alike in geological age and in manner of activity, the Manx volcanoes may be classed with the type of the puyes. . . .

"The volcanic rocks are . . . almost entirely confined to the range of cliffs and the ledges of the foreshore. Yet though thus extremely limited in area, they have been so admirably dissected along the coast, that they furnish a singularly ample body of evidence bearing on the history of Carboniferous volcanic action.

"Unfortunately the bottom of the volcanic group is nowhere visible. At the east or lower end of the series, exposed on the shore, an agglomerate with its dykes appears to truncate the Castletown Limestones. No trace of any tuff has been noticed among these lower limestones. We may infer that the volcanic energy began after they were deposited. The highest accessible portions of the volcanic group, as Mr. Horne showed, are clearly exposed on the coast at Poyll Vaaish, intercalated in and overlying the dark limestones of that locality. . . .

"Owing to irregularities of inclination the thickness of the Volcanic group can only be approximately estimated. It is probably not less than 200 to 300 feet. But as merely the edge of the group lies on the land, the volcanic rocks may reach a considerably greater extent and thickness under the sea. . . .

"The volcanic materials consist mainly of bedded tuffs, but include also several necks of agglomerate and a number of dykes and sills. . . . These Manx tuffs present many of the familiar features of those belonging to the puy-eruptions of Central Scotland, but with some peculiarities worthy of attention." . . .

¹ Quart. Journ. Geol. Soc., vol. xlvii, p. 449.

² Macmillan & Co., London. 2 vols. 1897. Vol. II. pp. 22-32.

"Their colour is the usual dull yellowish green, varying slightly in tint with changes in the texture of the materials, the palest bands consisting of the finest dust or volcanic mud. Great differences in the size of their fragmentary constituents may be observed in successive beds, coarse and fine bands rapidly alternating, with no admixture of non-volcanic sediment, though occasional layers of fine ash or mudstone . . . may be noticed.

"The materials of the tuffs are remarkably uniform in character and conspicuously volcanic in origin. With the exception of occasional blocks of limestone, which range up to masses several feet and occasionally several yards, in diameter, the dust, lapilli and included stones consist entirely of fragmentary basic lava, so persistent in its lithological features that we may regard its slightly different varieties as merely marking different conditions of the same rock.

"The accumulation of pumiceous ash in this southern coast of the Isle of Man is one of the most remarkable in Britain. As Mr. Hobson has well shown, the matrix of this tuff consists of irregular lapilli, representing what may have been various conditions of solidification in one original volcanic magma. This magma he has described as an 'augite-porphyrite' or olivine-basalt. Some of the lapilli, as he noted, consist of a pumice crowded with vesicles which occupy more space than the solid part; others show nearly as many vesicles but the glass is made brown by the number of its fine dust-like inclusions; a third type represents the cells and cell-walls in nearly equal proportions. The same observer found that where the substance is most cellular the vesicles, fairly uniform in size, measure about a tenth of a millimetre in longest diameter.

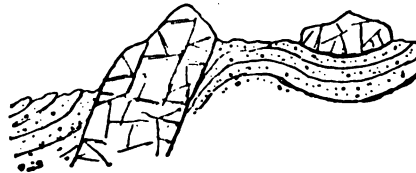
"An interesting feature of the tuffs is the abundant occurrence of loose felspar crystals throughout the whole group up to the highest visible strata. These crystals, sometimes nearly an inch in length, appear conspicuously as white spots on weathered surfaces of the rock. They are so much decayed, however, that it is difficult to extract them entire. On the most cursory inspection they are observed to enclose blebs of a greenish substance like the material that fills up the vesicles in the pumiceous fragments and in the pieces of cellular lava.

"I have not ascertained the original source of these scattered felspars. In one of the dykes on the north side of the agglomerate at Scarlet Point, as was pointed out by Mr. Hobson, large crystals of plagioclase occur in the melaphyre, but the felspars in the tuffs and agglomerates differ so much from these that we cannot suppose them to have come from the explosion of such a rock. I failed to detect any other mineral in detached crystals in the tuffs, but a more diligent search might reveal such, and afford some grounds for speculating on the probable nature of the magma from the explosion of which the scattered crystals were derived. It is at least certain that this magma must have included a large proportion of plagioclase crystals.

"Between the lapilli and the minute pumice-dust that constitute the matrix of this tuff much calcite may be detected. Though this mineral may have been partly derived from the decay of the felspar in the lava-fragments I believe that it is mainly to be attributed to the intermingling of fine calcareous ooze with the ash accumulated on the sea-floor.

"The stones imbedded in the tuff consist almost exclusively of slightly different varieties of the same rock—a pale, always vesicular rock, and sometimes pass into a coarse slag. They vary up to six feet or more in length; in many cases, they appear to have been derived from the disruption of already solidified lava, for their vesicles are not elongated or arranged with reference to the form of the block, but have been broken across and appear in section on the outer surface. In other instances, however, the cavities are large and irregular in the centre of the block, while

FIG. 61. "*Section of dyke and sill in the tuffs west of Scarlet Point, Isle of Man.*" (SIR A. GEIKIE.)



on the outside they are smaller and are drawn out round the rudely spherical shapes of the mass, as in true volcanic bombs.

"The limestone fragments enclosed in the tuff include pieces of the dark carbonaceous and of the pale encrinital varieties. In no case did I observe any sensible alteration of these fragments. They seem to have been derived from material disrupted and ejected during the opening of successive vents, and not to have been exposed for any considerable time to the metamorphic influence of volcanic heat and vapours."

Sir Archibald Geikie then discusses the dyke-like belts of basalt or diabase which traverse the ash and form an important constituent of the Volcanic Series, especially in the eastern portion of the exposure, between Scarlet Point and Cromwell's Walk. He observes regarding them, that "in their remarkably developed vesicular structure they look more like streams of lava than ordinary dykes. It is this structure which gives to these dykes their peculiar interest. Bands of vesicles, from an inch or less to several inches in breadth, run along the dykes parallel to the outer walls. Unlike the familiar rows of little amygdaloidal cells in ordinary basalt dykes, such as those of the Tertiary series in Scotland, these vesicles, though small and pea-like in the narrower bands towards the margin of the dykes,

become so large, numerous, and irregular, in the broader more central bands that the rock passes there into a slag."

This resemblance to a lava-flow is again commented on in description of the supposed sill at Cromwell's Walk, respecting which the following details are given:—

"There is, however, a peculiarity about the development of vesicular structure in this sill which I have not observed anywhere else. If we examine the southern side of the sill near its eastern end, we observe that the successive bands of vesicles are arranged in the same direction as the surface contact with the underlying tuffs, precisely as they are arranged in the dykes parallel to the bounding walls. So far the structure

FIG. 62. "*Section of south side of vesicular sill of Scarlet Point.*" (SIR A. GEIKIE.)

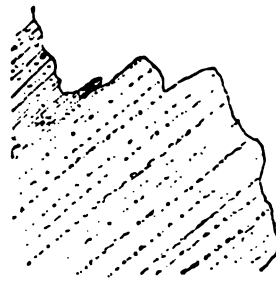


FIG. 63. "*Bands of vesicles in the same sill.*" (SIR A. GEIKIE.)



is quite normal. But, moving a few yards westwards, we find that the bands begin to curve, and, instead of following the contact surface, strike it first obliquely and then at right angles, until we have the structure shown in Fig. 63. The bands here vary from less than an inch to more than a foot in breadth and where broadest assume a slaggy texture."

After further discussion of the conditions of the eruption, which he believes to have taken place from several small vents between Scarlet Point and Poolvash, Sir A. Geikie concludes his description as follows:—

"As the records of the earliest eruptions during the Carboniferous Limestone period in the district of the Isle of Man are concealed, so also those of the last of the series lie under the sea. Where the highest visible tuffs overlie the Poyll Vaaish limestones they show no change in the nature of the materials ejected or in the energy of eruption. They lie so abruptly on the dark calcareous deposits as to show that a considerable pause in volcanic activity was followed by a violent explosion. The same abundant grey-green pumice, the same kind of loose crystals of felspar, the same type of lava-blocks and bombs as had characterized the foregoing eruptions remained as marked at the end. But the further volcanic records cannot be perused, and we are left to speculate whether the coast sections reveal almost the whole chronicle, or if they merely lay before us the early chapters of a great volcanic history of which the main records lie buried under the waves of the Irish Sea."

Further Account of the Volcanic Series.

The foregoing quotations will suffice to show the general character of the Carboniferous Volcanic rocks. Their exposure is practically confined to the coast line, the ground being cultivated up to the edge of the cliff and their inland extension probably nowhere exceeding more than 200 or 300 yards in breadth. The shelving rocky foreshore has a width varying from 100 yards at Scarlet to 170 yards near Poolvash, and this tract was mapped by Mr. A. Strahan and myself in 1892 on the scale of 25 inches to the mile. Some difficulties encountered at that time in the interpretation of the sections led me to make several subsequent re-examinations, but it was not until an opportunity occurred in 1897 for investigating the rocks around Scarlet Point with an exceptionally low tide that a clue to the unravelling of these difficulties was forthcoming.¹ As mentioned on a previous page, evidence was then found for overthrust movements of the volcanic rocks upon the Lower Limestone; and on pursuing this line of enquiry it was ascertained that many of the phenomena which had hitherto been assigned to volcanic activity were more

¹ See Annual Report of the Director General of the Geological Survey 1897, p. 110.

probably due to later disturbances by earth-movement. These results were confirmed during two subsequent visits to the outcrop under similar favourable conditions of tide, and a summary of my conclusions on the subject was brought before the Geological Society in 1899.¹ The disturbances were found to have affected every part of the outcrop, but were especially pronounced at the junction of the Volcanic rocks with the limestone at the eastern and at the western extremity of the exposure, and also in the vicinity of the dyke-like masses of vesicular basalt mentioned in the above-quoted description. Many of the intercalations of limestone with volcanic material, which have been supposed to denote intervals of quiescence between separate volcanic eruptions, I now believe to be displaced masses, dragged up along thrust-planes from the underlying limestone-floor; and most of the dyke-like bands of vesicular basalt I think may have originally been more or less horizontal lava-flows which have been tilted and sometimes broken into fragments during lateral movement of the whole mass. In the following pages the detailed evidence on which these conclusions are based will be presented.²

In considering this evidence, we will commence at the northern boundary of the Volcanic rocks at Poolvash, where the junction with the limestone has already been described, and will work thence southward to Scarlet Point.

It is curious to note that towards this boundary with the limestone, the ash presents in places a tendency to the dome-like arrangement so conspicuous in the underlying limestones. Near low-water-mark W.S.W. of Poolvash farm, 30 yards N. of the larger olivine-dolerite dyke, the following perplexing section is revealed in the steep edge of a gully in the rock-platform. (Fig. 64).

The limestone in this exposure is obviously not in its original position. The plane which defines the surface of the dome is probably an oblique section through a curving plane of slip or overthrust, along which a shred of limestone has been caught up and crumpled. In the crags on the opposite side of the gully, 30 or 40 yards N.W. of the above, the ash, which in this neighbourhood is of medium texture and not often distinctly bedded, shows some well-defined planes, along which there is an inch or

¹ "On some effects of earth-movement in the Carboniferous Volcanic rocks of the Isle of Man." *Quart. Journ. Geol. Soc.*, vol. lvi. (1900), pp. 11-25.

² Mrs. M. Ogilvie-Gordon has called attention to the similarity between the structures produced by disturbance in these rocks and those similarly produced in the Triassic rocks of the Enneberg area in South Tyrol, described in her papers in *Geol. Mag.*, dec. iv., vol. i. (1894), pp. 1-10 and 50-60, and *Quart. Journ. Geol. Soc.*, vol. lv. (1899), pp. 560-633. The phenomena in the Manx Carboniferous Volcanic Series are, however, apparently of a simpler character, and are on a much smaller scale than those in the Tyrol described by Mrs. Gordon (see letters in "*Nature*," vol. lxi. (1900), pp. 490 and 612, and vol. lxii. (1900), p. 7).

two of fine crushed material resting on an even, indurated surface of cherty ash. These are also probably lines of movement.

FIG. 64. Section in crag on shore near low-water W.S.W. of Poyllvaish Farm. Height about 10 feet.



A. Volcanic ash.

b. Dark cherty limestone and shale, with pyritous fossils; wisps of ash, one to three inches thick, are apparently pinched in between folds of the strip of limestone.

T. Curving plane, probably overthrust. A dorsal fish-spine (*Sphenacanthus*) was found in the ash a foot or two below the right-hand lower corner of the section (see p. 236).

Most of the lenticles of limestone in the ash are free from any ashy admixture; and I have always found it difficult to understand how this could have occurred if they had been deposited, as supposed, in separate little basins a few feet or yards across, surrounded on all sides by ridges of pumiceous volcanic detritus. To the westward of the above section, however, at extreme low-water between *Ghaw Gortagh* and *Poyll Vaish* of the six-inch map (see plan, Fig. 53), on a rock-platform much obscured by marine growths, there are some shreds of dark ashy limestone among the volcanic tuff. In only two or three other instances has limestone been observed with ashy fragments actually incorporated in it, though little wisps of ash between separate surfaces of limestone are not uncommon.

The margins of the included limestone-masses, both great and small, are usually characterized by cherty induration, probably from chemical reactions tending to silicification induced along the surfaces in contact with the ash. In the isolated limestone blocks embedded in the coarser volcanic agglomerates, the silicification generally extends through a deep outer crust which surrounds a less altered or unaltered interior;¹ but the thin contorted strips in the fine ash are altered throughout.

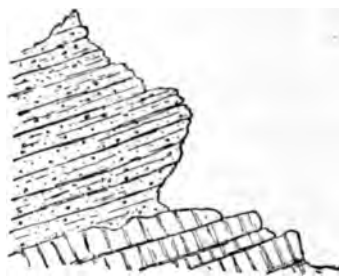
The evidences of overthrusting which are everywhere visible as we follow the junction of the Volcanic rocks with the limestone south-eastward across Poolvash Bay have already been described (pp. 224-5, Figs. 58, 59 and 60). The section on the foreshore south of the "black marble" quarry (Fig. 58) is especially instructive in showing how the top of the limestone-flags (*Posidonomya* beds) has been rucked up by the movement into sharp ridges, the crests

¹ See "Ancient Volcanoes," op. cit., pp. 25 and 26.

of which have been bent over towards the north and sometimes pinched off and carried up into the ash.

At *Close ny Chollagh Point*, about 50 yards S. of this section, there appears to be a lenticular band of dark flaggy limestone embedded in the ash. But when followed down along the foreshore, this band of limestone is found to be continuous with one of the anticlinal ridges shown in Fig. 58, p. 223; and its curiously irregular outline, cherty surface, and lack of continuity are at once explained when we recognise that it has been pinched up from below.

FIG. 65. *Section at foot of low cliff at Close ny Chollagh Point. "Limestone passing under stratified tuffs"* (SIR A. GEIKIE, "*Ancient Volcanoes*," vol. ii., Fig. 184).



In the little bay on the south side of *Close ny Chollagh Point*, 100 yards S. of the old fort, the cliff-section reveals a lenticular cake of grey fossiliferous limestone, about 40 yards long and six or eight feet in maximum thickness, underlain and overlain by ash, and dislocated midway by a small fault. Fossils occur here in the ash close to base of the limestone, including *Glyphioceras* (*Goniatites*) *striatum*, Sow., and *Spirifera* probably *bisulcata*.¹

This limestone-lenticle in general aspect differs from all the adjacent strips, bearing a closer resemblance to the pale Poolvash Limestone than to the dark *Posidonomya* flags. It is difficult to believe that this isolated patch, differing lithologically from the other patches and yet similarly unmixed with ash, is in its original position. The likelihood that it is a slice which has been ridged up and shaved away from below, is further supported by the indications of crushing which are visible around its margin. There appears to be some connection between this mass and the tongue of pale limestone which, as previously described (p. 217), juts out into the volcanic rocks in the field 200 yards inland south-eastward.

¹ These specimens were obtained by Mr. J. A. Howe during our recent visit together to the sections, and have kindly been presented by him to the Survey (L. 1743 and 1744).

The ash on the shore to the westward and south-westward of this section is frequently fine in texture and well bedded; and contains marine fossils, chiefly bits of the stems of encrinites. The finer beds occasionally pass into calcareous and sometimes nodular ashy flags; and regularly interbedded with these we find cherty layers of dark limestone, rarely more than an inch or two in thickness, evidently of contemporaneous deposition. These strata possess the true characters of passage-beds; and we should probably have found rocks of this kind forming a transition between the limestone and the ash in all the sections if the junction had been undisturbed. The surfaces of these laminated ash-beds are generally beautifully tessellated by close-set rectangular joints, sometimes not more than an inch apart; while in many places small faults break the continuity of the beds at intervals of a few feet, or even inches; and sooner or later the stratification becomes crumpled and confused, and the laminated series is merged into a mass of ash or agglomerate with twisted shreds of limestone, possessing only a rude platy structure which is probably of secondary origin. Though on a smaller scale, and among rocks very different in their present lithological condition, these phenomena recall structures common in the Borrowdale Volcanic Series of the Lake District, in such sections as those under the Sty-head Pass to which my attention was directed by Mr. Marr and Mr. Harker.

The accompanying copy of a photograph (Pl. iv. 2) taken by the former Director-General of the Survey during his later visit to the Island, illustrates the stratification and step-faulting in the ash between *Close ny Chollagh Point* and *Cromwell's Walk*. In this photograph, the pale layer in the middle of the section has been artificially whitened; this band is faulted down four times towards the right. In the upper right-hand corner, the stratification becomes confused and lost.

A little to the southward of *Close ny Chollagh Point*, we find, besides the interbedded calcareous layers, two much larger lenticular masses of black flaggy limestone 25 to 50 yards apart, extending from high-water mark across the foreshore, to below half-tide mark in bold curves more or less parallel to each other. If prolonged inland in the same direction, these strips would meet the protruding tongue of pale limestone mentioned in a preceding paragraph. At their junction with the tuff we find the usual indications of relative displacement, the bedded ash a little above the junction presenting the following section (Fig. 66), in which disruption of the original stratification by lateral movement is clearly exhibited.

Disturbances of this kind become more acute as we proceed southward; until at the little cliff at the end of a field-fence 450 yards south of the old fort at *Close ny Chollagh Point*, we reach a curious vertical wall of coarse agglomerate, made up of large blocks of vesicular basalt, apparently bursting through fine ash, and in places mixed with and overlain by

similar ash, but associated with and probably passing into solid mass of the basalt on the inland side of the section. This has been described as the site of a small volcanic vent. Li

FIG. 66. Section across the foreshore 250 yards S. of Close ny Chollagh Point, showing the disturbance of bedding in volcanic ash and limestone. Length about 100 yards.

(From Quart. Journ. Geol. Soc., vol lvi.)



- A. Evenly-bedded fine calcareous ash and thin cherty impure limestone-bands (6 feet seen).
- b. Ash and limestone, like that below, but crumpled, broken and confused.
- m. Small thrust-plane separating the broken from the unbroken beds; shifting to higher bands in going eastward. The ash is indurated for 2 or 3 inches beneath this plane.

the similar agglomerate between *Cromwell's Walk* and *Scarl Point*, presently to be discussed, there seems however much reason to believe that it may be a sill or lava-flow which has been displaced and brecciated.

GEOLOGY OF ISLE OF MAN.

PLATE III.



1. Coarse sedimentary below Cronwell's Walk. with



2. Tabular mass of Basalt at Cronwell's Walk. with

Forty yards south of the above section, the base of the cliff reveals a little dome of black cherty limestone 10 to 12 yards in diameter, with its convex upper surface singularly crumpled up among fine structureless ash, and its under surface resting in places on an obscurely exposed mass of basalt into which it appears to be pinched or folded.

Another and larger dome occurs at high-water mark 220 yards farther south. It shows the same peculiarities of structure, and contains, besides, some pebble-like inclusions of pale fossiliferous limestone, resembling in this respect the dark "pebbly" bands around the Poolvash knolls. One of the newer olivine-dolerite dykes bisects this dome.

It is characteristic of these limestone lenticles that they are almost invariably arched upwards, and not downwards as should have been the case if they had been deposited in hollows of the tuff on the sea-floor.

Between the last-mentioned section and Cromwell's Walk, the shore is constituted of broad bare platforms of ash, mostly of medium texture, with a platy structure suggesting incipient cleavage, but occasionally fine and well-bedded. At several places in these sections, indications of normal faulting may be observed; but the evidence is insufficient to prove the amount of throw, and the stratigraphy does not seem in any instance to be seriously affected by these fracture-lines. On the south side of an E.-W. dislocation due S. of "Burial Ground" (6 inch, sheet 16) a dyke-like ridge of vesicular basalt, varying from 2 feet to 7 feet in width, strikes S.S.E. across the foreshore; and 75 yards farther E. there occurs a smaller parallel vein of similar material about 4 inches wide. These bands are much jointed, and some of the joints form small step-faults like those in the laminated ash already described. The larger band is trenched near half-tide mark by a deep gully, and the cross-section therein exposed reveals a sharp ω -shaped curve, which is probably an incipient fold. This plication dies out towards low-water mark.

At Cromwell's Walk we reach the broad mass of basalt which presents the anomalous features commented on by Sir Arch. Geikie in passages above quoted.

Between low- and high-water, this basalt rises with steep walls through the ash like an ordinary dyke; but in the crags above high-water mark it rolls over north-eastward, and lies almost flat in a shallow trough of coarse agglomerate, with a little outlier of agglomerate upon its upper surface, here bearing more resemblance to a lava-flow than to a dyke. It is in this tabular portion that we find the exceptional arrangement of the vesicular structure described by Sir A. Geikie (see p. 232, Figs. 61, 62 and 63). Other peculiarities about this basalt also deserve close attention. Its steep south-western face, which is beautifully revealed in the cliff, has a curiously wrinkled surface, suggestive of a lava-flow; and is broken towards the base by a ledge, where a little crushed ash and

agglomerate comes in between two nearly parallel surfaces of the massive rock, with indications that there has been some degree of relative displacement between these surfaces.

Again, in the detached tabular mass just behind the crest of the cliff, we find that where the truncated stream-lines of vesicles occur, the margin of the solid basalt is fractured and gapped by sharp indentations from which irregular blocks have evidently been plucked, these indentations being now filled in with the ash and coarse agglomerate; and immediately beneath the basalt, the agglomerate is crushed and streaky. These features are illustrated in Pl. III., Fig. 2, and Pl. IV., Fig. 1, which are reproduced from photographs taken by Sir Arch. Geikie.

In the dyke-like ridge, the basalt is flanked on the south-west by ash of medium texture in which large blocks are rare; while the opposite or north-eastern side it is bordered by coarse agglomerate composed of subangular and rounded blocks of vesicular rock like that of the solid mass, with numerous small wisps and large rounded blocks of dark limestone with a cherty exterior. Towards low-water, inclusions of limestone increase in size and numbers; and at low tide, a dome-like mass of black limestone several yards in diameter is exposed among the agglomerate adjoining the ridge (see plan, Fig. 68). The character of the agglomerate a little above the principal limestone-dome is shown in Pl. III., Fig. 1, from a photograph by Sir A. Geikie; finer ash overlies the agglomerate in the background.

It is equally difficult to conceive either that the dome of limestone at this place could have been ejected from the volcano, or that it could have been originally deposited in its present position. But when the evidences of disruption and rearrangement in the vicinity are taken into account, it appears not improbable that the mass may have been pinched from the crest of a fold and carried along a thrust-plane, like the strata previously described. This explanation of course implies that the agglomerate now surrounding the limestone must also have undergone great deformation; and it becomes a matter for consideration how much of the structure of this agglomerate is due to the volcanic eruption, and how much to the breaking up of the rocks during the movement. That some part should be assigned to the latter cause is, I think, evident from the fractured condition of the margin of the basalt; as well as from the relative abundance of blocks of this rock near the solid mass, and of limestone near the dome of limestone. But, of course, in rocks of this character a brecciation-structure might readily be superinduced upon an original pyroclastic structure; and I must confess my inability to distinguish between the one and the other where both are represented in the same section.

I think, however, that the phenomena of this part of the coast, as a whole, may be best explained by regarding the vesicular



**1. Enlarged View of Gaps in lower margin of Basalt
at Cromwell's Walk.**



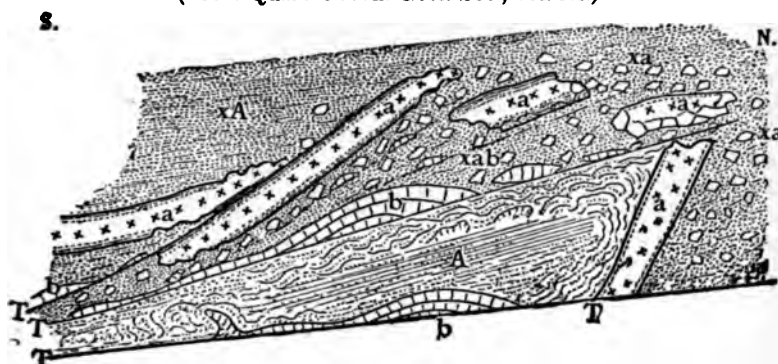
**2. Laminated Ash, with close-jointing and step-faulting;
800 yards south of Close ny Chollagh Point.**



basalt as a lava-flow which has been tilted on end and partly folded and driven forward among the surrounding ash by lateral pressure; and during the movement it appears probable that portions of the mass were brecciated, and thrust-planes developed along which wedges of limestone were dragged upwards from the underlying floor. This view is expressed in the following diagram.

FIG. 67. *Diagram to illustrate supposed structure of Volcanic rocks in vicinity of Cromwell's Walk.*

(From Quart. Journ. Geol. Soc., vol. lvi.)



- A. Volcanic Ash, much disturbed, but showing traces of original bedding.
- xA. Re-arranged Volcanic Ash.
- a. Vesicular basalt.
- xa. Coarse agglomerate of blocks of vesicular lava in ashy matrix.
- xab. The same, with some limestone blocks.
- b. Strips of limestone carried up along thrust-plane.
- T. Thrust-planes.

From *Cromwell's Walk* the ridge of basalt probably extends towards W.N.W. for some distance, roughly parallel to the cliff-line, at from 30 to 50 yards inland, as there are low bosses of similar rock here and there along this direction in the field in which a mound occurs, marked **Burial Ground** on the six-inch map. In the next field also there are similar bosses, along the line of a demolished fence; and if these indicate the further prolongation of the ridge it may possibly be continuous with the shattered basalt and coarse agglomerate already described, which just touches the cliff 450 yards south of *Close ny Chollagh Point*. On the published one-inch geological map these outcrops have been indicated as if definitely continuous, this being the only practicable method of representing them on so small a scale.

To the eastward towards low-water, the coarse agglomerate at *Cromwell's Walk* terminates suddenly against finer ash, along a plane which is probably in connection with the overthrust movement, though it has been interpreted as a normal fault by Mr. B. Hobson and as the wall of a small vent by Sir A. Geikie.

From *Cromwell's Walk* to the Stack of Scarlet, a distance of about 600 yards, the coast exposure reveals an exceedingly complex mass of ash and agglomerate, broken into by ridges

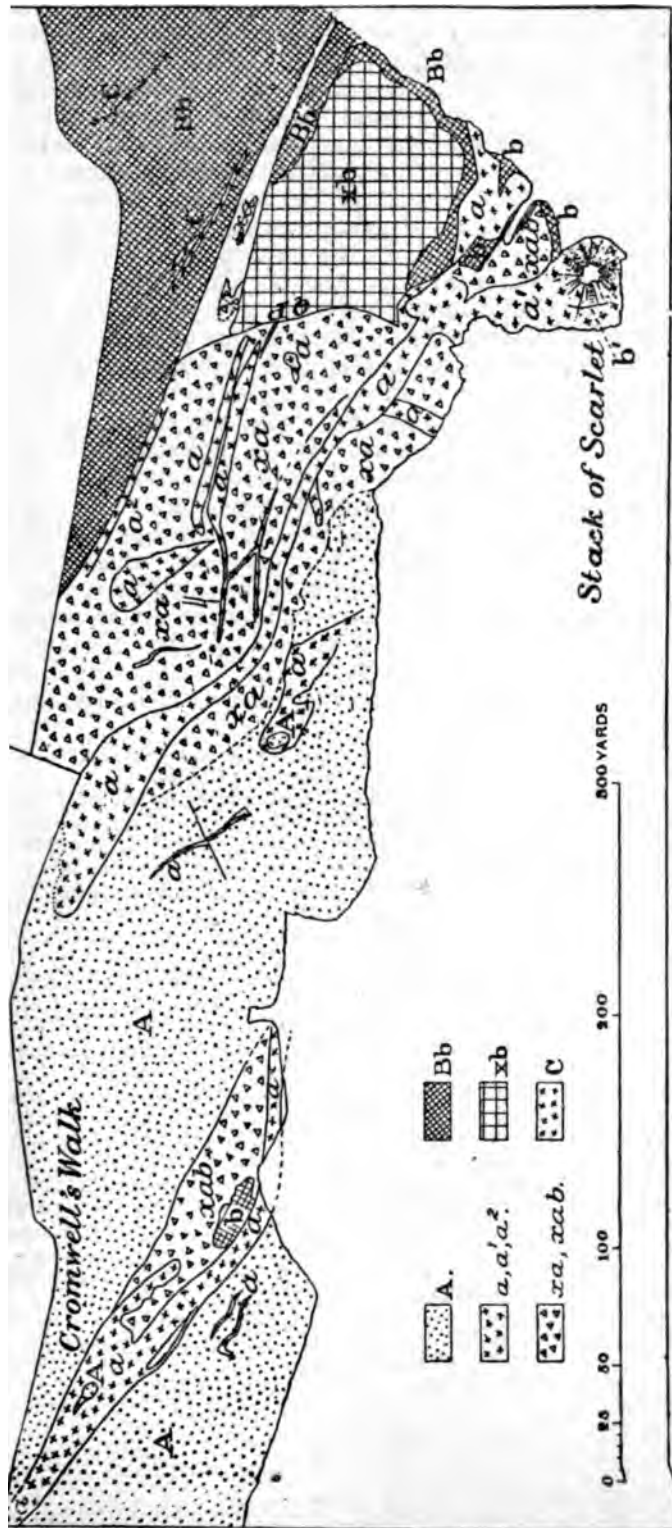
and irregular partially-brecciated masses of vesicular basalt; and among these rocks, as we approach the junction with the Lower Limestone, shreds and patches of dark flaggy limestone are again intricately mingled. As previously mentioned, this part of the outcrop has been carefully studied and mapped by Mr. B. Hobson¹ who, though chiefly concerned with their petrographical characters, noticed in several places the tilting and disturbance of the rocks.

In all essential particulars, these sections repeat the phenomena already described; and may be similarly explained. A massive belt of vesicular basalt has been ridged up and crushed in among less coherent ashy material and thinner bands of lava, causing general disruption and rearrangement. The plan (Fig. 68, p. 243) of this part of the coast has been copied from the 25-inch working map.

It has hitherto been commonly held that the principal vent of the volcano lay in this quarter, Clifton Ward, B. Hobson, and Professor Boyd Dawkins² considering the great block of columnar basalt which forms the Stack to mark the actual orifice, while other observers have thought that the site of the neck was indicated by the coarse agglomerate. But it is clear that lateral displacement has been rife in these rocks and has given rise to at least some of the phenomena which have been regarded as proving the proximity of the vent, so that I am now inclined to doubt whether the eruptive focus is anywhere revealed in the section. As at the western extremity of the outcrop so also at this place, it is in the relation of the limestone to the volcanic rocks that the most important evidence for this displacement is forthcoming. Between the smooth undulating scars of Lower Limestone on the northern side of Scarlet Point, and the rugged outcrop of the Volcanic Series, there intervenes a little shingly recess (indicated in Fig. 68 by the absence of shading), in which above half-tide level the solid rocks are for the most part hidden, though some low crags of brecciated vesicular basalt crop out near high-water mark. Immediately to the southward, abutting upon the volcanic rocks, we find a huge jagged mass of apparently unstratified limestone, about 100 yards long by 50 yards broad (xb. of Figs. 68 and 70), rising with steep sides several feet above the highest tides; and when closely examined the lower part of this mass is seen to be composed of recemented limestone-breccia. The shingle in the recess narrows towards low water; and during an exceptionally low ebb (of 21 feet) I have traced dark flaggy limestone right across the inlet, save for a gap of only 9 feet, which probably marks the position of an olivine-dolerite dyke, eroded out at this place, but still visible higher up the recess, where it traverses the Lower Limestone and strikes directly for the gap. Mr. Hobson suggests that the "melaphyre dyke"

¹ Quart. Journ. Geol. Soc., vol. xlvii., pp. 437-438.

² British Assoc. Rep. Liverpool, 1896, p. 776.



Volcanic Ash. a. Dyke-line ridges of vesicular basalt, probably disturbed lavas. a'. Columnar basalt, forming Stack of Scarlet, with (b')
 A. Undeveloped strip of limestone, 2 to 3 inches thick. a'. "Melaphyre Dyke" (of *Holston*). xa. Coarse agglomerate composed principally of basaltic
 includes in a matrix of ash. xa. Coarse agglomerate containing blocks of limestone as well as of basalt. Bb. Dark flaggy limestone (Lower
 blocks). b. Strip of dark flaggy limestone entangled among the Volcanic Series. xb. Mass of contorted and brecciated limestone, with
 Limestone, etc., and irregular strings of small quartz-pebbles (Q.P.) near western margin. C. Olivine-dolerite dykes (Tertiary?).

(a² of Fig. 68) which borders the Volcanic Series near the 'spring' 75 yards farther west may also occur in the gap, but I failed to find this rock or any other portion of the volcanic group in the lower part of the recess. The limestone on the southern side of the gap appears to correspond in every respect and to be identical with the Lower Limestone of the shore to the northward. These dark flaggy beds at low-water are thence continuous southward up to the steep margin of the massive limestone-breccia above described, and are then seen distinctly to pass beneath it in a well-defined platform, at the surface of which the flaggy layers are in places truncated. On this platform rests the thick bed of recemented limestone-breccia, quite free from volcanic admixture, which forms the basement of the unstratified mass. It is clear that we are dealing at this point with a thrust-plane, and this plane can be traced at the lowest tides around the eastern or seaward edge of the unstratified limestone. In the opposite direction, if we follow the gully to high-water mark we find the Lower Limestones apparently truncated by a fault of low hade, above which volcanic breccia is obscurely exposed. In the grassy ground above high-water mark, the ash and agglomerate terminate suddenly at a more steeply dipping plane which truncates the limestone. It has been suggested by Mr. Horne that this junction may indicate the actual wall of the crater, while Mr. Hobson seeks to explain the facts by supposing that a normal fault follows the line of the gully; but the phenomena are all compatible with the view that the junction is everywhere an overthrust.

That Cumming was aware of the essential facts in regard to the unstratified limestone is shown in the following passage:—

"The upper portion of the isolated and altered patch of limestone nearest the Stack appears by the included fossils, so far as they can be made out, to belong to the light coloured Poolvash limestone, but the lower portion may readily be observed as being the same with the black beds to the northward of the protruded amygdaloid and trap which have isolated this limestone boss. It is very unfortunate that at this point . . . the rocks should have been so much altered from their ordinary character."¹

It may be doubted however whether there is sufficient evidence to bear out the correlation of the unstratified limestone with the Poolvash Limestone. Cumming gives no list of the fossils on which his view was based; and as organic remains other than bits of encrinites are rare and fragmentary, it is probable that he trusted mainly to the pale colour and massive appearance of the rock. The presence, first noticed by Henslow,² of abundant rounded quartz-pebbles in the massive limestone around its north-western margin tells against this correlation, such pebbles being elsewhere extremely rare except only towards the base of the Lower Limestone (see p 193). These pebbles seem to indicate that the overthrust mass has been derived from beds lower than those on which it rests. Cumming may have had this pebbly limestone in mind in referring to rocks which "present appearances of a passage from true limestone into true trap,"³ as the material bears a superficial resemblance to some portions of the amygdaloidal lavas.

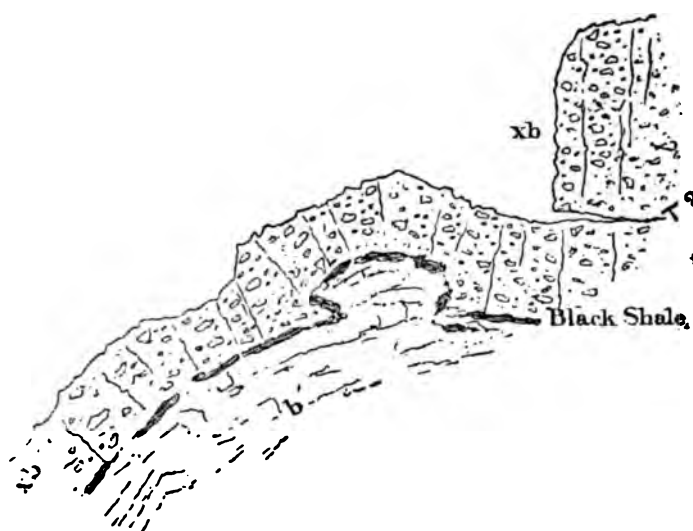
¹ "Isle of Man," p. 126. ² Trans. Geol. Soc., vol. v., p. 496.

³ "Isle of Man," p. 124.

Though the limestone-mass appears to have been more or less brecciated throughout, the upper part, where least obscured by recrystallization, dolomitization and cleavage-like jointing, sometimes shows traces of crumpled bedding forced up into domes, as represented in the following sketch (Fig. 69) of a small exposure in the heart of the boss.

FIG. 69. *Section in the brecciated limestone (xb of Fig. 68) at the northern side of Scarlet Point, showing traces of original bedding.*

Height about 6 feet, length 10 feet.



b. Much disturbed limestone, dolomitised in places; with traces of original bedding here and there, capped by a torn and interrupted strip of black shale 1 to 2 inches thick.

xb. Grey limestone-breccia, made up of recemented fragments of all sizes, with bits of encrinites and fragmentary shells.

T. i. Probably a minor thrust-plane.

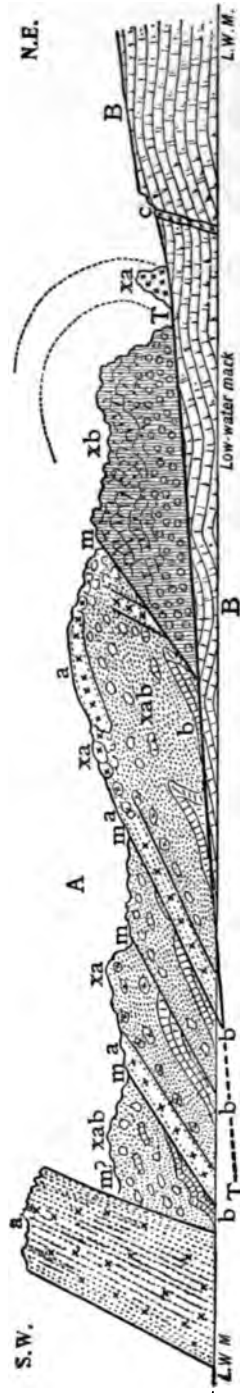
The recognition of the overthrust at the base of the massive limestone affords the key to the interpretation of the rest of the section. Great blocks of vesicular basalt and agglomerate, confusedly intermingled with shreds of limestone, abut against the southern and western flank of the mass, and are continuous thence up to the Stack. The following section shows the principal facts of these exposures and their theoretical interpretation. (Fig. 70).

At extreme low-water, pinched-up ridges of dark flaggy limestone are visible here and there in deep crannies worn into the volcanic rocks in this space right up to the northern flank of the Stack, and the coast is skirted by tabular reefs, covered at the lowest tides by only a few feet of water, which from their shape are most probably of limestone. The whole evidence strongly

FIG. 70. *Diagrammatic section across Scarlet Point west of the Stack, showing the probable relation of the Volcanic Series to the Carboniferous Limestone.*

(From Quart. Journ. Geol. Soc., vol. lvi.)

Length of section about 150 yards; maximum height about 40 feet.



- A. Volcanic series; ash, agglomerate and vesicular basalt.
- a. Dyke-like mass of vesicular basalt.
- xa. Coarse agglomerate; large blocks of vesicular basalt in an ashy matrix.
- xab. Similar agglomerate, with some limestone blocks.
- B. Lower Limestone rising into shallow domes.
- b. Strips of limestone dragged up into the Volcanic series.
- xb. Mass of contorted and brecciated limestone.
- C. Olivine-dolerite dyke (Tertiary ?).
- T. Major thrust-plane. m. Minor thrust-planes.

suggests that the platform of Lower Limestone underlying the major thrust-plane is continuous at least as far as the northern edge of the Stack, dipping gently southward beneath the volcanic rocks. In the coarse agglomerate, rounded and spindle-shaped pieces of cherty limestone are rather abundant, but no fragments of the Carboniferous Basement Conglomerate nor of the Manx Slates were observed, though these strata probably exist within 200 or 300 feet of the surface and must have been perforated if any volcanic orifice had opened up in this quarter. In the confused ground to the north of the Stack a little arch of dark flaggy limestone, 10 to 15 yards in diameter, with bedding well preserved, apparently resting upon a sloping plane of basalt (see Figs. 68 and 70), has always constituted one of the most difficult problems of the section, and one for which no satisfactory solution has been afforded in the previous literature of the subject. But it is in all respects similar to the lenticles which have previously been described, and like them is probably the portion of a fold torn off and carried forward along a thrust-plane. It seems to be connected with the pinched-up ridge which occupies the cranny running south-eastward from it.

The Stack itself consists of a mass of basalt which, on all sides except the north, goes steeply down into deep water; the less coherent ash and agglomerate in which it was no doubt once embedded having been stripped away by the sea. It exhibits a rude columnar structure, best seen on its summit, the columns being nearly vertical. Such columns are formed perpendicular to the cooling surfaces, so that if the Stack had been, as supposed, the core of a vertical orifice in which lava has cooled, the columns should have been horizontal, and not vertical. The rock has an indistinct platy structure, suggestive of rude cleavage, which strikes N. and S. and traverses the columns. A little strip of baked cherty limestone, 2 to 3 inches thick, apparently a fragment caught up by the molten material in its flow, lies embedded in the igneous rock on the western side of the Stack.¹

LHEEAH RIO.—Reference has previously been made (p. 202) to the fact that Lheeah Rio, the insulated reef in Castletown Bay nearly three-quarters of a mile E.N.E. of Scarlet Point, is largely if not entirely composed of massive basic igneous rock. I examined the reef during a 19-feet ebb, and found every part then above water to be of only one kind of igneous rock. As seen afterwards from the shore at the time of an exceptional ebb of 21 to 22 feet, there appeared to be much more bare scar than I had gained footing upon; and the reef might repay further examination during such an ebb, though probably much that seems from a distance to be rock would be found to show only the tops of the tall laminarian seaweeds, growing in a few feet of water. The reef has a length of about 150 yards, with an extreme breadth of 50 yards, and, even in that portion which I examined, presents the largest homogeneous outcrop of intrusive material within the Carboniferous basin. Its position and dimensions associate it with the Volcanic Series, but petrographical examination seems to indicate that its affinity is with the olivine-dolerite dykes rather than with the diabase of the Stack

¹ See Hobson, *op. cit.*, p. 436.

(see p. 326). Unfortunately the circumstances of its exposure leave its stratigraphical relations entirely conjectural. Except for the petrological evidence, I should have regarded it as part of the Volcanic Series and as an indication that the portion of the series concealed by the sea was of great extent and thickness.

Concluding Notes on the Southern Carboniferous Basin.

In concluding this chapter I propose briefly to restate the general deductions drawn from the observed facts.

The indications of overthrusting at the junction of the Volcanic Series with the limestone imply that the original sequence between these rocks may not anywhere be preserved. The laminated character of the least disturbed portions of the tuff, and the presence of marine remains in it, show that the products of the eruption must have fallen into the sea, even if the volcano were not wholly submarine. But the absence of volcanic material from any portion of the limestone below the mass of eruptive rocks indicates that the volcanic episode took place after the deposition of the mass of the limestones. The first invasion of tuff seems, however, to have followed immediately upon the deposition of the Posidonomya Beds at the top of the limestone-sequence; and the thin crumpled shreds of ashy limestone among the disturbed ash above the overthrust are probably the remnants of beds which once existed at the true base of the Volcanic series. The preponderance of tuff in the lower part of the series probably signifies that the present outcrop lay at some little distance from the centre of eruption, and that the strip now above sea-level occurred on the flank of the volcano. As the eruption continued, basic lava flowed out over the ashes and became interbedded with them; and at a later stage some dykes or sills of similar composition, including the "melaphyre dyke" near Scarlet, seem to have been injected into them. During subsequent overthrusting, the rigidity of these sheets of basalt gave rise to great relative displacement between them and the softer deposits with which they were associated; they were snapped into huge blocks, which ploughed through the ash and were tilted and partly brecciated during the process. Owing to the unequal pressures impinging on the limestone-floor during these movements, the limestone was ridged up into steep shallow folds, the crests of which were sometimes torn off and involved in the superincumbent moving mass.

By the northward overthrusting of the Volcanic Series, the Posidonomya Beds have probably been in great part overridden and concealed. Owing to the lack of inland exposures there is much uncertainty as to the manner in which the overthrusts pass from higher to lower horizons in the limestone when followed eastward from Poolvash to Scarlet, but they appear to cross the strata obliquely, cutting the Posidonomya Beds at Poolvash, the Poolvash Limestone in the vicinity of Close ny

Chollagh Point, and the Lower Limestone farther eastward. There is also difficulty in explaining the absence of the displaced portion of the limestone above the thrust-plane in the vicinity of Scarlet if, as seems necessary, we reject Cumming's supposition that this portion is represented by the mass of limestone-breccia at the margin of the Volcanic rocks. It has not, indeed, been absolutely proved that the black flaggy beds underlying the Volcanic rocks on the southern side of the little recess north of Scarlet Point belong to the Lower Limestone; and there is a bare possibility that they may represent the Posidonomya Beds brought in by a fault against rocks of similar aspect belonging to the Lower Limestone on the north. But, as already stated, I could find no evidence for this fault at low water, and Cumming was also of opinion that the Lower Limestone extended across the recess.

The probable explanation is that the movement was everywhere as complex as in the sections which have been described and figured above, and that the displacement was effected by the development of numerous minor planes throughout the mass of the volcanic rocks rather than by movement *en bloc* above a single plane.

The general tendency of the movement seems to have been towards the production of an anticline along an E.S.E. to W.N.W. axis, ranging from Scarlet Point to Poolvash. If the beds had been of more homogeneous and pliant composition it is probable that the requisite lateral shortening would have been attained by a system of simple folds. But the rigid sheets of basalt, lying among softer material and under no great superincumbent weight, were incapable of more than incipient folding, and were broken and overthrust all along the crest of the anticline. The general effect has been to roll forward the Volcanic series, as it were, piecemeal upon the limestone. The localisation of the more intense results of the disturbance to the Volcanic rocks is thus the direct consequence of their lithological characters.

While in the crush-conglomerates of the Manx Slates, described in a previous chapter, there are indications of great superincumbent pressure and shearing in every particle of the mass, the Carboniferous Volcanic rocks seem to have suffered disruption and rearrangement comparatively near the surface, where pressure was not severe and the fractured strata were comparatively free to move. Under such conditions, brecciation has been produced without any trace of deformation in the intimate rock-structure, and the separate blocks have been pushed along with as little interstitial alteration as the boulders in and under a glacier.

Brecciation of this type may be described as "brecciation-without-crushing," as distinguished from the "brecciation-with-crushing" which is seen in the slate-rocks.

Returning now to the discussion of the knoll-structure in the Poolvash Limestone, it will be observed that the knolls

very thin. The material
disappeared almost on
contact. I could have been
deceived but for the yellow
color and texture.

Continuing Notes

In continuing the
general description of the
series.

The relations of the
series with the lower
sequences remain
character of the last
portion of the series to
disappear and now it
is widely distributed.
any portion of the series
indicates that the re-
sult of the mass of
series, however, is a
series of the Position
sequence and the
among the disturbed
remains of some of
the series. The
the series probably at
little distance from
the surface sea-level
the eruption began
and became marine
dikes or sills of similar
type. Near Scars
During subsequent
basalt gave rise to
and the other deposits
were stopped into a
ash and were tilted
Owing to the unequal
during these movements
shallow beds, the con-
nected in the super-

By the northward
Positioned Beds has
and extended. Owing
much uncertainty as
from higher
followed by a
cross the
Positioned

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The general tendency of the movement seems to have been towards the production of an anticline along an E.S.E. to N.W. axis, ranging from Scarlet Point to Poolvash. If the beds had been of more homogeneous and pliant composition it is probable that the requisite lateral shortening would have been attained by a system of simple folds. But the rigid sheets of salt, lying among softer material and under no great superimposed weight, were incapable of more than incipient folding, and were broken and overthrust all along the crest of the anticline. The general effect has been to roll forward the Volcanic rocks, as it were, piecemeal upon the limestone. The localisation of the more intense results of the disturbance to the Volcanic rocks is thus the direct consequence of their lithological characters.

While in the crush-conglomerates of the Manx Slates, described in a previous chapter, there are indications of great superimposed pressure and shearing in every particle of the mass, the Carboniferous Volcanic rocks seem to have suffered disruption and rearrangement comparatively near the surface, where pressure was not so great, and the fractured strata were comparatively free to move. Under such conditions, brecciation has been common, and the trace of deformation in the Manx rocks is confined to separate blocks which have been imbedded in the interstitial material as the rubble of a wall. Recent observations on the brecciation of the rocks from the Manx Slates, and the structure in the knolls

curiously encircle the northern margin of the volcanic area. As mentioned on p. 210, my first opinion was that these knolls were original structures, due to the accumulation and rapid consolidation of limestone-reefs on the Carboniferous sea-floor; but since observing how severely the volcanic rocks had been affected by earth-movement, I have felt less assured on this point. Mr. J. E. Marr has recently claimed¹ that somewhat similar though much larger limestone-knolls in Yorkshire and Lancashire have been formed by earth-movement; and though Mr. Marr's hypothesis of cumulative overthrusting could scarcely apply to knolls so small as those of Poolvash, it must be acknowledged that these are very likely to have been in some degree modified during the overthrusting of the Volcanic rocks, since they lie partly within and partly along the borders of the zone of disturbance in which the production of dome-like ridges is not unusual. On the other hand, there seems to be clear evidence of different stages of unequal accumulation among the limestones, beginning in the hummocky surfaces so common in the Lower Limestones (p. 199), increasing in the small bosses among the *Posidonomya* Beds like those described and figured on p. 227, and still further expanding in the lenticular swellings of limestone-bands as shown in Fig. 54, p. 213. The difference between the fauna of the knolls and that of the surrounding strata, strongly insisted upon by Cumming: the great abundance of fossils in the knolls, and their uncrushed condition: and the scarcely less excellent state of preservation of those in the enfolding flaggy beds: are circumstances difficult of explanation if we regard the structures as due solely to earth-movement. We are hampered in the discussion by the lack of definite information as to the upward sequence from the top of the Lower Limestones, and especially as to the original thickness of the Poolvash Limestone and of the *Posidonomya* Beds. A patient re-examination and correlation of the faunas of these different divisions is also needed; and until such data have been accumulated it is perhaps advisable to leave the matter *sub judice*.

The structure of the Southern Carboniferous Basin as a whole, with its Basement Conglomerate outcropping at Port St. Mary on the western edge, as well as at Langness on the eastern and at Athol Bridge and Cass ny Hawin on the northern, fully justifies Cumming's observation that its Volcanic rocks occupy the centre of a trough. It is true that the trough is wide and shallow, but none the less it is in the bottom of the basin that lateral pressure would be developed most forcibly by the inward tilting of the sides.

It is clear from the undisturbed manner in which the Carboniferous Basement Conglomerate rests upon the Manx Slates that the Post-Carboniferous movements have had little or no effect upon the rigid floor of these previously folded rocks;

¹ "On Limestone Knolls in the Craven District of Yorkshire and elsewhere," *Quart. Journ. Geol. Soc.*, vol. lv. (1899), pp. 327-358.

and the displacements within the boundaries of the Carboniferous seem to have attained their greatest intensity at some distance above this unyielding base, the strata resting immediately upon the rigid floor being less disturbed than those higher in the series where the freedom of movement was greater.

In the south of the Island the evidence merely shows that the movements were Post-Lower-Carboniferous; but in other quarters a narrower time-limit is indicated. In the deep borings in the north of the Island, (see Chap. VII. p. 280), Triassic and so-called Permian strata were found to rest nearly horizontally and undisturbed, in sharp unconformability, upon the eroded upturned edges of Lower Carboniferous rocks tilted at a high angle and much disturbed, proving severe movements of Pre-Permo-Triassic age. The same Post-Lower-Carboniferous but Pre-Triassic movements (Stage 6. of the classification in Chap. III. p. 72) seem also to have affected the Peel Sandstones of the western coast (see pp. 272-3).

Palæontology of the Carboniferous Rocks.

As previously mentioned, though a few Manx fossils have been described in special monographs since Cumming's list was issued in 1848, no later work on the subject as a whole has yet been published. It was not found possible during the present survey to devote much time to the collection of the Carboniferous fossils, but an attempt has been made in the list which follows to illustrate the palæontology of the deposits, by using the material available in several private collections generously placed at our disposal by the owners.

Cumming's list included 222 species, of which 13, considered by him to be new, were denoted by MS. names without figures or description. His collection is still preserved in the museum of King William's College at Castletown, but has unfortunately fallen into disorder, so that the majority of the specimens are now either without labels, or with labels insufficient for their identification. By permission of the authorities of the College, we were allowed to pick out the labelled specimens, in which species equivalent to about one half of Cumming's list were represented, and these were re-determined in the Palæontological Department of the Survey and returned to the College. It was at first intended to work out Cumming's synonymy in regard to these species, but the old nomenclature was in some instances so erratic that the intention was abandoned, as it was suspected that the labels had in some cases been shifted from their original specimens. These fossils from the Cumming collection, along with a few collected during the course of the Survey and others previously contained in the Jermyn Street Museum, were arranged under the stratigraphical divisions adopted by Cumming, and became the basis of the present list, which was then augmented to its present

length by the examination of the collections of Miss C. Birley, Mr. R. Law, F.G.S.,¹ and the Woodwardian Museum of Cambridge, and by the addition of species recorded in the special monographs mentioned at the head of the list. Dr. Wheelton Hind has also supplied us with a list of the Manx lamellibranchs and a few other forms contained in his own and other collections which he has personally examined. To him and to the owners of the collections above-mentioned our hearty thanks are due for their unstinted assistance. These sources are indicated in the Table by initial letters, and in the fourth column the authority for the determination is given.

The list contains a total of 237 species, as against the 222 species recorded by Cumming; but from the method in which it has been compiled, it is necessarily of unequal value for the different branches of the fauna. It is especially rich in Lamellibranchs, owing to Dr. Hind's assistance; in Cephalopods and Brachiopods is adequate but not exhaustive; while in Gasteropods, Trilobites and Corals it is poorer than Cumming's list and is frankly insufficient. Cumming also records three species of fish from the Lower Limestone and one from the *Posidonomya* beds; and five plants (*Adiantum*, *Pecopteris*, *Sphenopteris nervosa*, Brongn., *Lepidostrobus ornatus*, Brongn., and *Calamites*) from the last-mentioned beds; all of which are now unrepresented among the labelled specimens preserved in the College Museum collection at Castletown. Stratigraphically, it is in regard to the *Posidonomya* beds that our present list is most deficient as compared with its forerunner, Cumming having paid especial attention to this division, whereas most later collectors have been chiefly attracted to the more prolific Poolvash and Lower Limestones.

In the Lower Limestones the most conspicuous fossils are the larger corals, *Zaphrentis*, etc.; *Productus giganteus*, and other brachiopods; and large cephalopods, including *Prolecanites compressus* (better known as *Goniatites Henslowi*) (Fig. 71), *Solenocheilus*, *Temnocheilus*, etc.

The Poolvash Limestone, as already described, is in many places a mass of beautifully preserved shells, brachiopods predominating in one spot, cephalopods in another, while corals are comparatively rare, though they abound in the dark flaggy and shaly beds which surround and overlap the knolls of this limestone (see p. 214).

The characteristic fossil of the *Posidonomya*-beds is the lamellibranch *Posidonomya Becheri* (Fig. 73), but as Dr. Hind remarks, it is only found in certain bands.

The fossils in the Volcanic Ash have been much neglected, and those at present known are not sufficiently numerous to be

¹ Mr. Law's collection of the Manx Carboniferous fossils, especially of those of the Poolvash Limestone, is of the most extensive character. The cephalopods and lamellibranchs alone have been laid under contribution for the present list, as time did not permit the examination of the whole.

orth showing in a separate column in the table. Fragments of encrinite stems are the most common remains; in the Cum-
 ing collection there is an example of *Posidonomya Becheri* in

FIG. 71.

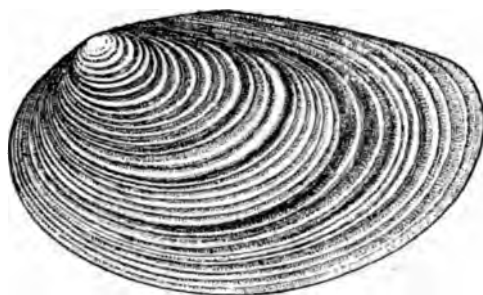


FIG. 72.



a, b, c. *Prolecanites compressus*, J. Sowerby, sp. Lower Limestone.
 arlet, Isle of Man; a, and b, about $\frac{1}{2}$ nat. size; c, about $\frac{1}{2}$ nat. size.
 from "British Museum Cat. Foss. Cephalopoda," pt. iii., p. 245.)

FIG. 73.



Posidonomya Becheri, Goldf. Carboniferous Limestone Series. Figured
 in a specimen in the Survey Collection from near Bamburgh, Northum-
 berland.

ashy matrix; and, as mentioned on p. 235, during our recent
 visit to the sections Mr. J. A. Howe found a dorsal fish-spine
Phenacanthus (*Ctenacanthus*) 5 inches in length in the ash near
 water mark at Poolvash, and *Glyphioceras* (*Goniatites*)
iatum and *Spirifera* (probably *bisulcata*) in the same material
 the low cliff at Close ny Chollagh (see p. 236).

[POSTSCRIPT, AUGUST, 1902.—Reference has been made above to Cumming's discovery of plant-remains in the *Posidonomya* Beds, and to the absence of the original specimens from the Cumming Collection in the College Museum, Castletown. We have, however, been informed recently by Dr. Wheelton Hind, that fresh specimens of these plants have been obtained by Mr. D. Tait while collecting at Poolvash for the 'Carboniferous Zones Committee' of the British Association. The specimens were found in a band of black shale among the hummocks of limestone containing marine fossils, and included the following plants:—*Adiantites Machaneki*, Stur.; *Adiantites antiquus*, Ett.; *Sphenopteris pachyrachis*, Göpp.; *Sphenopteris pachyrachis*, var. *stenophylla*, Göpp.; and *Sphenopteris* allied to *Sph. bifida*, L. and H., or *Sph. subgeniculata*, Stur.]

The bed also contained the following mollusca:—*Posidonomya Becheri*; *Aviculopecten papyraceus* (thus proving the existence of this species in the Island and settling the doubt expressed in a footnote on p. 259); *Orthoceras morrisianum*; *Orthoceras sulcatum*; and *Glyphioceras* resembling *Glyph. crenistria* or *Glyph. reticulatum*.]

As Dr. Wheelton Hind is at present engaged in a critical study of the British Carboniferous fauna, and has personally investigated the Manx deposits with this object in view, he has at our request kindly prepared the following notes on the general aspect of the Manx fauna and its relations with the Carboniferous faunas of the mainland:—

"In reviewing, as a whole, the Carboniferous fossils of the Isle of Man, it cannot be said that the fauna is in any way local or peculiar, except in the number of individuals present. One shell, *Allorisma monensis*, Hind, may prove to occur only in the island, and this shell does seem to be characteristic of the Lower Limestones, only being found with *Edmondia sulcata*, Phill.sp., and *Prolecanites compressus*, Sow. (*Gon. Henslowi*), at Scarlet and Ballasalla. The fauna of the Poolvash Limestone may be said to be identical with the faunas which are found in the shelly limestones of the Craven district of Yorkshire, Clitheroe, (Lancashire), Castleton, Park Hill, and Thorpe Cloud (Derbyshire), and Wetton, Narrowdale, and Gateham (Staffordshire), though individuals of the Cephalopoda are much more numerous in the Isle of Man.

"In my opinion, in S.W. Yorkshire, Derbyshire, and Staffordshire the lower beds are rarely exposed, and, consequently, to a very large extent we are ignorant of any special fauna they may contain; but at Clitheroe the Carboniferous Limestone consists of a series of bedded limestones at the base, much resembling the Scarlet and Ballasalla limestones in appearance, and an upper series of obscurely bedded, white, richly fossiliferous beds, which

probably represent the Poolvash beds, and accumulated under similar conditions. The fauna of the lower part of the limestones, as exposed at Kendal Fell, Westmoreland, appears to me to closely resemble that of the Lower Limestones of the Isle of Man, and, amongst others, *Edmondia sulcata* and *Prolecanites compressus*, which are not met with in the upper beds of either the Midlands or the Isle of Man, are found there. The Knife Scar limestones of Shap also have a very similar fauna, and this bed is supposed to belong to the Melmerby Scar series, the northern representatives of the Great Scar Limestone. The limestones of the Furness district appear to have a series of bedded limestone at the base, with massive limestone above, but fossils are not present in any large number, but corals are, as in the Isle of Man, only found in numbers in the lower beds, and *Productus giganteus* appears to have lived during the whole of the deposit of both upper and lower beds, as in the Isle of Man, and to pass upwards in the Furness district into a thin band of limestone which is separated from the main mass by a hundred feet or so of shales, which is the upper limit at which this fossil occurs. I doubt whether *Edmondia sulcata* can in any way be claimed to be characteristic of the lower limestones, except that I have not yet seen it in any of the shelly white limestones either of the Isle of Man or north central England. But this shell occurs at, at least, two horizons in Wensleydale, in the shales below the Hardraw Scar, and in the Middle Limestone.

"In the Isle of Man it seems impossible to make out the exact relationship of the shelly limestones to the well-bedded or Lower series. It is at present impossible to determine whether or no the isolated masses of shell limestone were original local structures, or were due to the denudation of a sheet, which was cut up into masses by exposure to the usual weathering agents, or by exposure on a foreshore, some slight horizontal movements subsequently complicating their stratigraphical arrangement.

"The *Posidonomya* beds are of interest, from the peculiar fossils they contain, and from their local character.

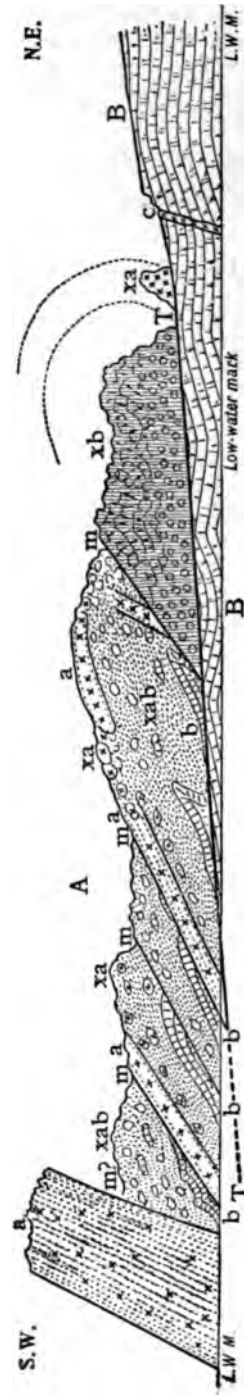
"The beds are found over a very small area only, and appear to be due to a local more or less estuarine phase in the upper part of the series of bedded limestones, and their relation to the white shelly limestone is very questionable. All previous observers have considered the *Posidonomya* beds to be stratigraphically above the white shelly limestones, and to represent the last phase of the Carboniferous deposits in the south of the Island, but the section at the black marble quarry can hardly be interpreted in this way.

"The fauna of these beds consists of flattened casts of an ovate lamellibranch, *Solenomya costellatus*, McCoy, which I have also obtained from the 4 Laws Limestone of Northumberland,

FIG. 70. *Diagrammatic section across Scarlet Point west of the Stack, showing the probable relation of the Volcanic Series to the Carboniferous Limestone.*

(From Quart. Journ. Geol. Soc., vol. lvi.)

Length of section about 150 yards; maximum height about 40 feet.



- A. Volcanic series; ash, agglomerate and vesicular basalt.
- a. Dyke-like mass of vesicular basalt.
- xa. Coarse agglomerate; large blocks of vesicular basalt in an ashy matrix.
- xab. Similar agglomerate, with some limestone blocks.
- B. Lower Limestone rising into shallow domes.
- b. Strips of limestone dragged up into the Volcanic series.
- xb. Mass of contorted and brecciated limestone.
- C. Olivine-dolerite dyke (Tertiary).
- T. Major thrust-plane. m. Minor thrust-planes.

uggests that the platform of Lower Limestone underlying the major thrust-plane is continuous at least as far as the northern edge of the Stack, dipping gently southward beneath the volcanic rocks. In the coarse agglomerate, rounded and spindle-shaped pieces of cherty limestone are rather abundant, but no fragments of the Carboniferous Basement Conglomerate nor of the Manx Slates were observed, though these strata probably exist within 200 or 300 feet of the surface and must have been perforated if any volcanic orifice had opened up in this quarter. In the confused ground to the north of the Stack a little arch of dark flaggy limestone, 10 to 15 yards in diameter, with bedding well preserved, apparently resting upon a sloping plane of basalt (see Figs. 68 and 70), has always constituted one of the most difficult problems of the section, and one for which no satisfactory solution has been afforded in the previous literature of the subject. But it is in all respects similar to the lenticles which have previously been described, and like them is probably the portion of a fold torn off and carried forward along a thrust-plane. It seems to be connected with the pinched-up ridge which occupies the cranny running south-eastward from it.

The Stack itself consists of a mass of basalt which, on all sides except the north, goes steeply down into deep water; the less coherent ash and agglomerate in which it was no doubt once imbedded having been stripped away by the sea. It exhibits a rude columnar structure, best seen on its summit, the columns being nearly vertical. Such columns are formed perpendicular to the cooling surfaces, so that if the Stack had been, as supposed, the core of a vertical orifice in which lava has cooled, the columns should have been horizontal, and not vertical. The rock has an indistinct platy structure, suggestive of rude cleavage, which strikes N. and S. and traverses the columns. A little strip of baked cherty limestone, 2 to 3 inches thick, apparently a fragment caught up by the molten material in its flow, lies embedded in the igneous rock on the western side of the Stack.¹

LEECH RIF.—Reference has previously been made (p. 202) to the fact that Leech Rife, the insulated reef in Castletown Bay nearly three-quarters of a mile E.N.E. of Scarlet Point, is largely if not entirely composed of massive basic igneous rock. I examined the reef during a 19-feet ebb, and found every part then above water to be of only one kind of igneous rock. As seen afterwards from the shore at the time of an exceptional ebb of 21 to 22 feet, here appeared to be much more bare scar than I had gained footing upon; and the reef might repay further examination during such an ebb, though probably much that seems from a distance to be rock would be found to be only the tops of the tall laminarian seaweeds, growing in a few feet of water. The reef has a length of about 150 yards, with an extreme breadth of 50 yards, and, even in that portion which I examined, presents the largest homogeneous outcrop of intrusive material within the Carboniferous basin. Its position and dimensions associate it with the Volcanic Series, but petrographical examination seems to indicate that its affinity is with the olivine-dolerite dykes rather than with the diabase of the Stack

¹ See Hobson, *op. cit.*, p. 436.

(see p. 326). Unfortunately the circumstances of its exposure leave its stratigraphical relations entirely conjectural. Except for the petrological evidence, I should have regarded it as part of the Volcanic Series and as an indication that the portion of the series concealed by the sea was of great extent and thickness.

Concluding Notes on the Southern Carboniferous Basin.

In concluding this chapter I propose briefly to restate the general deductions drawn from the observed facts.

The indications of overthrusting at the junction of the Volcanic Series with the limestone imply that the original sequence between these rocks may not anywhere be preserved. The laminated character of the least disturbed portions of the tuff, and the presence of marine remains in it, show that the products of the eruption must have fallen into the sea, even if the volcano were not wholly submarine. But the absence of volcanic material from any portion of the limestone below the mass of eruptive rocks indicates that the volcanic episode took place after the deposition of the mass of the limestones. The first invasion of tuff seems, however, to have followed immediately upon the deposition of the Posidonomya Beds at the top of the limestone-sequence; and the thin crumpled shreds of ashy limestone among the disturbed ash above the overthrust are probably the remnants of beds which once existed at the true base of the Volcanic series. The preponderance of tuff in the lower part of the series probably signifies that the present outcrop lay at some little distance from the centre of eruption, and that the strip now above sea-level occurred on the flank of the volcano. As the eruption continued, basic lava flowed out over the ashes and became interbedded with them; and at a later stage some dykes or sills of similar composition, including the "melaphyre dyke" near Scarlet, seem to have been injected into them. During subsequent overthrusting, the rigidity of these sheets of basalt gave rise to great relative displacement between them and the softer deposits with which they were associated; they were snapped into huge blocks, which ploughed through the ash and were tilted and partly brecciated during the process. Owing to the unequal pressures impinging on the limestone-floor during these movements, the limestone was ridged up into steep shallow folds, the crests of which were sometimes torn off and involved in the superincumbent moving mass.

By the northward overthrusting of the Volcanic Series, the Posidonomya Beds have probably been in great part overridden and concealed. Owing to the lack of inland exposures there is much uncertainty as to the manner in which the overthrusts pass from higher to lower horizons in the limestone when followed eastward from Poolvash to Scarlet, but they appear to cross the strata obliquely, cutting the Posidonomya Beds at Poolvash, the Poolvash Limestone in the vicinity of Close ny

Chollagh Point, and the Lower Limestone farther eastward. There is also difficulty in explaining the absence of the displaced portion of the limestone above the thrust-plane in the vicinity of Scarlet if, as seems necessary, we reject Cumming's supposition that this portion is represented by the mass of limestone-breccia at the margin of the Volcanic rocks. It has not, indeed, been absolutely proved that the black flaggy beds underlying the Volcanic rocks on the southern side of the little recess north of Scarlet Point belong to the Lower Limestone; and there is a bare possibility that they may represent the Posidonomya Beds brought in by a fault against rocks of similar aspect belonging to the Lower Limestone on the north. But, as already stated, I could find no evidence for this fault at low water, and Cumming was also of opinion that the Lower Limestone extended across the recess.

The probable explanation is that the movement was everywhere as complex as in the sections which have been described and figured above, and that the displacement was effected by the development of numerous minor planes throughout the mass of the volcanic rocks rather than by movement *en bloc* above a single plane.

The general tendency of the movement seems to have been towards the production of an anticline along an E.S.E. to W.N.W. axis, ranging from Scarlet Point to Poolvash. If the beds had been of more homogeneous and pliant composition it is probable that the requisite lateral shortening would have been attained by a system of simple folds. But the rigid sheets of basalt, lying among softer material and under no great superincumbent weight, were incapable of more than incipient folding, and were broken and overthrust all along the crest of the anticline. The general effect has been to roll forward the Volcanic series, as it were, piecemeal upon the limestone. The localisation of the more intense results of the disturbance to the Volcanic rocks is thus the direct consequence of their lithological characters.

While in the crush-conglomerates of the Manx Slates, described in a previous chapter, there are indications of great superincumbent pressure and shearing in every particle of the mass, the Carboniferous Volcanic rocks seem to have suffered disruption and rearrangement comparatively near the surface, where pressure was not severe and the fractured strata were comparatively free to move. Under such conditions, brecciation has been produced without any trace of deformation in the intimate rock-structure, and the separate blocks have been pushed along with as little interstitial alteration as the boulders in and under a glacier.

Brecciation of this type may be described as "brecciation-without-crushing," as distinguished from the "brecciation-with-crushing" which is seen in the slate-rocks.

Returning now to the discussion of the knoll-structure in the Poolvash Limestone, it will be observed that the knolls

curiously encircle the northern margin of the volcanic area. As mentioned on p. 210, my first opinion was that these knolls were original structures, due to the accumulation and rapid consolidation of limestone-reefs on the Carboniferous sea-floor; but since observing how severely the volcanic rocks had been affected by earth-movement, I have felt less assured on this point. Mr. J. E. Marr has recently claimed¹ that somewhat similar though much larger limestone-knolls in Yorkshire and Lancashire have been formed by earth-movement; and though Mr. Marr's hypothesis of cumulative overthrusting could scarcely apply to knolls so small as those of Poolvash, it must be acknowledged that these are very likely to have been in some degree modified during the overthrusting of the Volcanic rocks, since they lie partly within and partly along the borders of the zone of disturbance in which the production of dome-like ridges is not unusual. On the other hand, there seems to be clear evidence of different stages of unequal accumulation among the limestones, beginning in the hummocky surfaces so common in the Lower Limestones (p. 199), increasing in the small bosses among the *Posidonomya* Beds like those described and figured on p. 227, and still further expanding in the lenticular swellings of limestone-bands as shown in Fig. 54, p. 213. The difference between the fauna of the knolls and that of the surrounding strata, strongly insisted upon by Cumming: the great abundance of fossils in the knolls, and their uncrushed condition: and the scarcely less excellent state of preservation of those in the enfolding flaggy beds: are circumstances difficult of explanation if we regard the structures as due solely to earth-movement. We are hampered in the discussion by the lack of definite information as to the upward sequence from the top of the Lower Limestones, and especially as to the original thickness of the Poolvash Limestone and of the *Posidonomya* Beds. A patient re-examination and correlation of the faunas of these different divisions is also needed; and until such data have been accumulated it is perhaps advisable to leave the matter *sub judice*.

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Cumming's list included 222 species, of which 13, considered by him to be new, were denoted by MS. names without figures or description. His collection is still preserved in the museum of King William's College at Castletown, but has unfortunately fallen into disorder, so that the majority of the specimens are now either without labels, or with labels insufficient for their identification. By permission of the authorities of the College, we were allowed to pick out the labelled specimens, in which species equivalent to about one half of Cumming's list were represented, and these were re-determined in the Palæontological Department of the Survey and returned to the College. It was at first intended to work out Cumming's synonymy in regard to these species, but the old nomenclature was in some instances so erratic that the intention was abandoned, as it was suspected that the labels had in some cases been shifted from their original specimens. These fossils from the Cumming collection, along with a few collected during the course of the Survey and others previously contained in the Jermyn Street Museum, were arranged under the stratigraphical divisions adopted by Cumming, and became the basis of the present list, which was then augmented to its present

length by the examination of the collections of Miss C. Birley, Mr. R. Law, F.G.S.,¹ and the Woodwardian Museum of Cambridge, and by the addition of species recorded in the special monographs mentioned at the head of the list. Dr. Wheelton Hind has also supplied us with a list of the Manx lamellibranchs and a few other forms contained in his own and other collections which he has personally examined. To him and to the owners of the collections above-mentioned our hearty thanks are due for their unstinted assistance. These sources are indicated in the Table by initial letters, and in the fourth column the authority for the determination is given.

The list contains a total of 237 species, as against the 222 species recorded by Cumming; but from the method in which it has been compiled, it is necessarily of unequal value for the different branches of the fauna. It is especially rich in Lamellibranchs, owing to Dr. Hind's assistance; in Cephalopods and Brachiopods is adequate but not exhaustive; while in Gasteropods, Trilobites and Corals it is poorer than Cumming's list and is frankly insufficient. Cumming also records three species of fish from the Lower Limestone and one from the *Posidonomya* beds; and five plants (*Adiantum*, *Pecopteris*, *Sphenopteris nervosa*, Brongn., *Lepidostrobus ornatus*, Brongn., and *Calamites*) from the last-mentioned beds; all of which are now unrepresented among the labelled specimens preserved in the College Museum collection at Castletown. Stratigraphically, it is in regard to the *Posidonomya* beds that our present list is most deficient as compared with its forerunner, Cumming having paid especial attention to this division, whereas most later collectors have been chiefly attracted to the more prolific Poolvash and Lower Limestones.

In the Lower Limestones the most conspicuous fossils are the larger corals, *Zaphrentis*, etc.; *Productus giganteus*, and other brachiopods; and large cephalopods, including *Prolecanites compressus* (better known as *Goniatites Henslowi*) (Fig. 71), *Solenocheilus*, *Temnocheilus*, etc.

The Poolvash Limestone, as already described, is in many places a mass of beautifully preserved shells, brachiopods predominating in one spot, cephalopods in another, while corals are comparatively rare, though they abound in the dark flaggy and shaly beds which surround and overlap the knolls of this limestone (see p. 214).

The characteristic fossil of the *Posidonomya*-beds is the lamellibranch *Posidonomya Becheri* (Fig. 73), but as Dr. Hind remarks, it is only found in certain bands.

The fossils in the Volcanic Ash have been much neglected, and those at present known are not sufficiently numerous to be

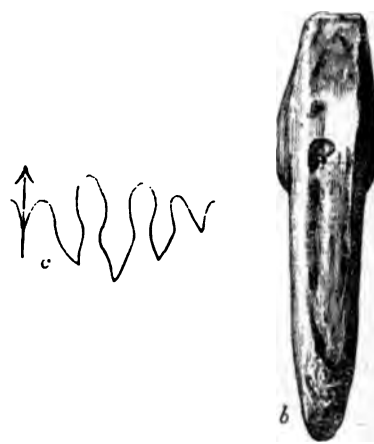
¹ Mr. Law's collection of the Manx Carboniferous fossils, especially of those of the Poolvash Limestone, is of the most extensive character. The cephalopods and lamellibranchs alone have been laid under contribution for the present list, as time did not permit the examination of the whole.

worth showing in a separate column in the table. Fragments of encrinite stems are the most common remains; in the Cumming collection there is an example of *Posidonomya Becheri* in

FIG. 71.

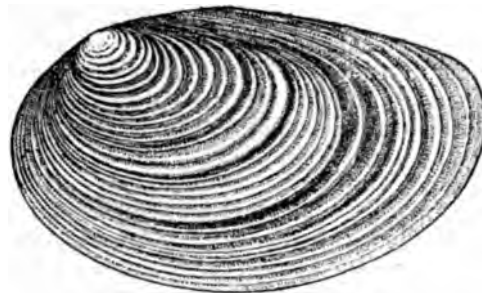


FIG. 72.



a, b, c. *Prolecanites compressus*, J. Sowerby, sp. Lower Limestone. Scarlet, Isle of Man; a, and b, about $\frac{1}{2}$ nat. size; c, about $\frac{1}{4}$ nat. size. (From "British Museum Cat. Foss. Cephalopoda," pt. iii., p. 245.)

FIG. 73.



Posidonomya Becheri, Goldf. Carboniferous Limestone Series. Figured from a specimen in the Survey Collection from near Bamburgh, Northumberland.

an ashy matrix; and, as mentioned on p. 235, during our recent visit to the sections Mr. J. A. Howe found a dorsal fish-spine *Sphenacanthus* (*Ctenacanthus*) 5 inches in length in the ash near low-water mark at Poolvash, and *Glyphioceras* (*Goniatites*) *striatum* and *Spirifera* (probably *bisulcata*) in the same material in the low cliff at Close ny Chollagh (see p. 236).

[POSTSCRIPT, AUGUST, 1902.—Reference has been made above to Cumming's discovery of plant-remains in the *Posidonomya* Beds, and to the absence of the original specimens from the Cumming Collection in the College Museum, Castletown. We have, however, been informed recently by Dr. Wheelton Hind, that fresh specimens of these plants have been obtained by Mr. D. Tait while collecting at Poolvash for the 'Carboniferous Zones Committee' of the British Association. The specimens were found in a band of black shale among the hummocks of limestone containing marine fossils, and included the following plants:—*Adiantites Machaneki*, Stur.; *Adiantites antiquus*, Ett.; *Sphenopteris pachyrachis*, Göpp.; *Sphenopteris pachyrachis*, var. *stenophylla*, Göpp.; and *Sphenopteris* allied to *Sph. bifida*, L. and H., or *Sph. subgeniculata*, Stur.]

The bed also contained the following mollusca:—*Posidonomya Becheri*; *Aviculopecten papyraceus* (thus proving the existence of this species in the Island and settling the doubt expressed in a footnote on p. 259); *Orthoceras morrisianum*; *Orthoceras sulcatum*; and *Glyphioceras* resembling *Glyph. crenistria* or *Glyph. reticulatum*.]

As Dr. Wheelton Hind is at present engaged in a critical study of the British Carboniferous fauna, and has personally investigated the Manx deposits with this object in view, he has at our request kindly prepared the following notes on the general aspect of the Manx fauna and its relations with the Carboniferous faunas of the mainland:—

"In reviewing, as a whole, the Carboniferous fossils of the Isle of Man, it cannot be said that the fauna is in any way local or peculiar, except in the number of individuals present. One shell, *Allorisma monensis*, Hind, may prove to occur only in the island, and this shell does seem to be characteristic of the Lower Limestones, only being found with *Edmondia sulcata*, Phill.sp., and *Prolecanites compressus*, Sow. (*Gon. Henslowi*), at Scarlet and Ballasalla. The fauna of the Poolvash Limestone may be said to be identical with the faunas which are found in the shelly limestones of the Craven district of Yorkshire, Clitheroe, (Lancashire), Castleton, Park Hill, and Thorpe Cloud (Derbyshire), and Wetton, Narrowdale, and Gateham (Staffordshire), though individuals of the Cephalopoda are much more numerous in the Isle of Man.

"In my opinion, in S.W. Yorkshire, Derbyshire, and Staffordshire the lower beds are rarely exposed, and, consequently, to a very large extent we are ignorant of any special fauna they may contain; but at Clitheroe the Carboniferous Limestone consists of a series of bedded limestones at the base, much resembling the Scarlet and Ballasalla limestones in appearance, and an upper series of obscurely bedded, white, richly fossiliferous beds, which

probably represent the Poolvash beds, and accumulated under similar conditions. The fauna of the lower part of the limestones, as exposed at Kendal Fell, Westmoreland, appears to me to closely resemble that of the Lower Limestones of the Isle of Man, and, amongst others, *Edmondia sulcata* and *Prolecanites compressus*, which are not met with in the upper beds of either the Midlands or the Isle of Man, are found there. The Knife Scar limestones of Shap also have a very similar fauna, and this bed is supposed to belong to the Malmerby Scar series, the northern representatives of the Great Scar Limestone. The limestones of the Furness district appear to have a series of bedded limestone at the base, with massive limestone above, but fossils are not present in any large number, but corals are, as in the Isle of Man, only found in numbers in the lower beds, and *Productus giganteus* appears to have lived during the whole of the deposit of both upper and lower beds, as in the Isle of Man, and to pass upwards in the Furness district into a thin band of limestone which is separated from the main mass by a hundred feet or so of shales, which is the upper limit at which this fossil occurs. I doubt whether *Edmondia sulcata* can in any way be claimed to be characteristic of the lower limestones, except that I have not yet seen it in any of the shelly white limestones either of the Isle of Man or north central England. But this shell occurs at, at least, two horizons in Wensleydale, in the shales below the Hardraw Scar, and in the Middle Limestone.

"In the Isle of Man it seems impossible to make out the exact relationship of the shelly limestones to the well-bedded or Lower series. It is at present impossible to determine whether or no the isolated masses of shell limestone were original local structures, or were due to the denudation of a sheet, which was cut up into masses by exposure to the usual weathering agents, or by exposure on a foreshore, some slight horizontal movements subsequently complicating their stratigraphical arrangement.

"The *Posidonomya* beds are of interest, from the peculiar fossils they contain, and from their local character.

"The beds are found over a very small area only, and appear to be due to a local more or less estuarine phase in the upper part of the series of bedded limestones, and their relation to the white shelly limestone is very questionable. All previous observers have considered the *Posidonomya* beds to be stratigraphically above the white shelly limestones, and to represent the last phase of the Carboniferous deposits in the south of the Island, but the action at the black marble quarry can hardly be interpreted in this way.

"The fauna of these beds consists of flattened casts of an ovate lamellibranch, *Solenomya costellatus*, McCoy, which I have also obtained from the 4 Laws Limestone of Northumberland,

wo cephalopods, *Orthoceras sulcatum*, Flem., and *Discites sulatus* (?), Sow., and the well-known *Posidonomya Becheri* itself, also always flattened. I fancy the three forms, *Pos. Becheri*, *Pos. lateralis*, and *Pos. gracillima*, Cumming, will turn out to be all one species. This fossil is always found in shale, and is by no means common, though, when it does occur, individuals are plentiful. It occurs at Venn, near Barnstaple, in beds considered to be Upper Culm, associated with *Orthoceras*; and some shales which have been baked by contact with a volcanic dyke at Budle Bay, Northumberland, also contain *Posidonomya Becheri* in abundance, associated with *Lingula squamiformis*, a lamellibranch of doubtful genus, *Bellerophon Urei* and *Chonetes laguessiana*. I have this year [1900] obtained *Pos. Becheri* at three localities in S. W. Yorkshire, in shales immediately above the 'massif' of limestone, and from the extremely narrow horizon in which this species occurs, I have hope that its presence may indicate a definite zone. It will thus be noted that the fauna which occurs with *Pos. Becheri* in each case is a peculiar one, and contains none of the species so common in the Carboniferous Limestones. Von Koenen has noted the occurrence at Herborn of the special Kulm Fauna, which occurs with *Pos. Becheri* (Neues Jahrbuch für Min. Geol. u. Palæont., 1879, p. 309), and I am of opinion that the change of fauna is entirely due to a change of environment, the organisms which inhabited the clearer sea bottom being unable to survive in the muds of the *Posidonomya* shales, and in no way due to the dying out of a previous fauna and the coming on of new types."

LIST OF CARBONIFEROUS LIMESTONE FOSSILS FROM THE SOUTH
OF THE ISLE OF MAN, based on material in the following
collections :—

Miss Birley's collection, marked B. ; the labelled specimens in the Cumming collection (*see above*), marked C. ; Dr. Wheelton Hind's collection, marked H. ; Mr. R. Law's collection,* marked L. ; the Geological Survey collection, marked S. ; the Cambridge Woodwardian Museum collection, marked W.

The addition of a ? to the initial indicates that doubt exists as to the horizon from which the fossil was obtained.

The letters in the fourth column denote the authority for the determinations, thus :—D.=Davidson, Monog. Brit. Carb. Brach., Pal. Soc. ; F.=Foord & Crick, Cat. Foss. Cephal. Brit. Mus. ; J.=Jones, Kirby & Brady, Monog. Carb. Ostracoda., Pal. Soc. ; H.=Determined by Dr. Wheelton Hind ; S.=Determined or verified by the Palæontological Department of the Survey ; CR.=Determined by Mr. G. C. Crick

* Mr. Law's collection contains several examples of a small spindle-shaped organism from the Poolvash Limestone which Dr. W. Hind thinks is probably *Fusulina*. Unfortunately no internal structure is apparent in the specimens.

	Lower or Castletown Limestone ¹	Poolvaah Limestone.	Post- donomya Beda.	Authority.
CœLENTERATA.				
<i>us coralloides</i> , <i>Sow.</i> - -	H	B	-	S H
<i>yllum fungites</i> , <i>Flem.</i> - -	B	-	-	S
<i>p.</i> - - - - -	-	S	-	S
<i>phyllum</i> sp. - - - -	B	-	-	S
<i>as parasitica</i> , <i>Phill.</i> - -	-	-	C ? S	S
<i>otion basaltiforme</i> , <i>Com. & Phill.</i> - -	-	W	-	S
<i>cæspitosum</i> , <i>Mart.</i> - -	B	-	-	S
<i>irregulare</i> , <i>Phill.</i> - -	W	-	-	S
<i>junceum</i> , <i>Flem.</i> - -	C	-	-	S
<i>nia favosa</i> , <i>Goldf.</i> - -	B	-	-	S
<i>megastoma</i> , <i>Phill.</i> - -	B C	-	-	S
<i>dipora tumida</i> , <i>Phill.</i> - -	S C	-	-	S
<i>itis</i> (<i>Campophyllum</i>) <i>cylindrica</i> , <i>Scouler</i> - -	B	-	-	S
<i>patula</i> ? <i>Mich.</i> - -	W	-	-	S
<i>sp.</i> - - - - -	B	-	-	S
ECHINODERMATA.				
<i>Crinoidea.</i>				
<i>rinus</i> ? - - - - -	-	H	S	S
<i>rinus crassus</i> , <i>Mart.</i> - -	B	-	-	S
<i>sp.</i> - - - - -	B	-	-	S
<i>Echinoidea.</i>				
<i>cidaris Urei</i> , <i>Flem.</i> - -	B	-	-	S
ANNELIDA.				
<i>es carbonarius</i> , <i>M'Coy</i> - -	B	-	-	?
CRUSTACEA.				
<i>Ostracoda.</i>				
<i>a chrysalidea</i> , <i>de Kon.</i> - -	-	S C ? J	-	S J
<i>ellina Burrovi</i> , <i>J. & K.</i> - -	-	B	-	S
<i>nella Cummingi</i> , <i>J. K. & B.</i> - -	-	S J	-	S J
<i>sp.</i> - - - - -	C ?	-	-	S
<i>na primaeva</i> , <i>M'Coy</i> - -	-	C ? W	-	S J ³
<i>phillipsiana</i> ? <i>Jones</i> - -	-	W	-	S
<i>sp.</i> - - - - -	B	-	-	S
<i>conchus orbicularis</i> , ? <i>J.K. & B.</i> - -	-	J	-	J
<i>" Scouleri</i> , <i>M'Coy</i> - -	-	C ? H	-	J
<i>simplex</i> ? <i>J. & K.</i> - -	-	-	-	J
<i>Burrovi</i> , <i>J. & K.</i> - -	-	B	-	J

specimens in the first column (Lower Limestone) were chiefly from Castletown and Ballasalla quarries and from the shore at Ronaldsway, Castletown and Balladoole.

Examined at British Museum.

Probably *Cyprina ovalis* of Cumming." (J. K. & B.)

	Lower or Castletown Limestone.	Poolvaah Limestone.	Post- donomaya L.s. da.	Authority.
CRUSTACEA —continued.				
<i>Trilobita.</i>				
Griffithides seminiferus, <i>Phill.</i>	-	C ? W	-	S
Phillipsia derbiensis, <i>Mart.</i>	-	C ? H	-	S H
" Eichwaldi, <i>Fisch.</i>	-	C ?	-	S
POLYZOA.				
Fenestella membranacea ? <i>Phill.</i>	-	C ?	-	S
" plebeia, <i>M'Coy</i>	-	C ?	-	S
" polyporata, <i>Phill.</i> (multi- porata, <i>M'Coy</i>).	-	W	-	S
Glauconome grandis, <i>M'Coy</i>	-	C ?	-	S
Rhabdomeson sp.	-	C ?	-	S
BRACHIOPODA.				
Athyris ambigua, <i>Sow.</i>	-	B	-	S D
" expansa, <i>Phill.</i>	-	C ?	-	S
" globularis, <i>Phill.</i>	-	-	-	D
" planosulcata ? <i>Phill.</i>	-	B	-	S
" Royssi, <i>Lév.</i>	-	-	-	D
Camarophoria crumena, <i>Mart.</i>	-	-	-	D
" globulina, <i>Phill.</i>	-	C ?	-	S
Chonetes buchiana, <i>de Kon.</i>	-	H	-	H
" laguessiana, <i>de Kon.</i>	-	-	-	D
" papilionacea, <i>Phill.</i>	-	B C ? D	-	S D
Dielasma (Terebratula) hastata, <i>J. de C. Sow.</i>	-	C ? B S	-	S D
" sacculus, <i>Mart.</i>	-	B	-	S D
Orthia Michelini, <i>Lév.</i>	-	C ?	-	S D
" resupinata, <i>Mart.</i>	-	B C ?	-	S D
" var. gibbera, <i>Portl.</i>	-	H	-	H
Orthotetes crenistria, <i>Phill.</i>	-	C	-	S D
Productus aculeatus, <i>Mart.</i>	-	S W D	-	S D
" Cora, <i>d'Orb.</i>	-	D	-	S D
" costatus, <i>J. de C. Sow.</i>	-	B	-	S D
" fimbriatus, <i>J. de C. Sow.</i>	-	C ?	-	S D
" giganteus, <i>Mart.</i>	-	C B	-	S D H
" " var. hemisphaericus, <i>Sow.</i>	-	C	-	S
" latissimus, <i>Sow.</i>	-	H	-	H D
" longispinus, <i>Sow.</i>	-	S D	-	S D
" mesolobus, <i>Phill.</i>	-	H D	-	H D
" proboscideus, <i>de Vern.</i>	-	-	-	-
" punctatus, <i>Mart.</i>	-	W B D	-	S D
" pustulosus, <i>Phill.</i>	-	-	-	D
" scabriculus, <i>Mart.</i>	-	C ? W S D	-	S D
" semireticulatus, <i>Mart.</i>	-	B S D	-	S D
" " var. Martini, <i>Sow.</i>	-	C W	-	S
" spinulosus, <i>Sow.</i>	-	-	-	D
" striatus, <i>Fisch.</i>	-	C ? W	-	S D
" tessellatus, <i>de Kon.</i>	-	-	-	D
" undatus, <i>DeFr.</i>	-	B W D	-	S D

	Lower or Castile town Limestone.	Poolvaah Limestone.	Post- donomya Beds.	Authority.
BRACHIOPODA—continued.				
<i>Rhynchonella acuminata</i> , Mart. -	-	C ? B	-	S D
" <i>angulata</i> , Linn. -	-	S B	-	S D
" <i>flexistria</i> , Phill. -	-	-	-	D
" <i>pleurodon</i> , Phill. -	-	B S	-	S D
" <i>pugnus</i> , Mart. -	-	B S	-	S D
" <i>reniformis</i> , J. de C. Sow. -	-	-	-	D
" <i>trilatera</i> , de Kon. -	-	-	-	D
<i>Spirifera convoluta</i> , Phill. -	C ?	-	-	S
" <i>duplicicosta</i> , Phill. -	B	B S D	-	S D
" <i>glabra</i> , Mart. -	C ¹ D	B S C	-	S D
" <i>integricosta</i> , Phill. -	-	B	-	S D
" (<i>Reticularia</i>) <i>lineata</i> , Mart. -	B	S B H	-	S D
" " var. <i>elliptica</i> , Phill. -	-	H	-	H
" <i>ovalis</i> , Phill. -	B C	S B	-	S D
" <i>pinguis</i> , Sow. -	C ?	-	-	S D
" <i>planata</i> , Phill. -	-	-	-	D
" <i>rhomboidea</i> , Phill. -	-	-	-	D
" <i>striata</i> , Mart. -	-	B	-	S D
" <i>triangularis</i> , Mart. -	-	-	-	D
" <i>trigonalis</i> , Mart. -	B (? sp) C	S B	-	S D
" " var. <i>bisulcata</i> Sow. -	B	S	-	S
<i>Spiriferina cristata</i> ? <i>Schloth.</i> -	-	C ?	-	S
" <i>insculpta</i> , Phill. -	B (? sp)	-	-	S D
" <i>laminosa</i> , M'Coy -	-	-	-	D
<i>Streptorhynchus</i> (see <i>Orthotetes</i>).				
<i>Strophomena rhomboidalis</i> , Wilck., var. <i>analoga</i> , Phill. -	D	S W D	-	S D
<i>Syringothyris cuspidata</i> , Mart. -	-	-	-	D
" <i>distans</i> , J. de C. Sow. -	-	B	-	S
LAMELLIBRANCHIATA.²				
<i>Allorisma monensis</i> , W. Hind, -	H L B	-	-	H
<i>Avicula</i> (<i>Leiopteria</i>) <i>informis</i> , M'Coy -	-	W	-	S
" <i>laminosa</i> , Phill. -	-	H	-	H
" <i>lunulata</i> , Phill. -	-	H	-	H
" <i>squamosa</i> , Phill. -	-	C ?	-	S
<i>Aviculopecten arenosus</i> , Phill. -	-	C ?	-	S
" <i>celatus</i> ? M'Coy -	-	W	-	S
" <i>docens</i> , M'Coy -	-	W	-	S
" <i>dumontianus</i> , de Kon. -	-	C ?	-	S
" <i>incrassatus</i> , M'Coy -	C ?	-	-	S
" <i>Murchisoni</i> ? M'Coy -	C ?	-	-	S
" <i>planoradiatus</i> , M'Coy -	C ?	S	-	S
" <i>variabilis</i> , M'Coy -	-	-	C ?	S

¹ In limestone with quartz-pebbles, labelled "Ballahot." (Cumming coll.)² The Cumming collection contained specimens of *Aviculopecten papyraceus* and *Nuculana attenuata*, but the labels do not state the locality, and Dr. W. Hind informs us that the fossils are probably not Marx.

	Lower or Castletown Limestone.	Poolvaah Limestone	Posi- donomya Beds.	Authority.
LAMELLIBRANCHIATA—continued.				
Cardiomorpha Egertoni, <i>M'Coy</i>	-	H	-	H
" obliqua, <i>W. Hind</i>	-	H	-	H
" oblonga, <i>Phill.</i>	-	H	-	H
Cypricardella Annæ, <i>de Ryckholt</i>	-	H	-	H
Edmondia laminata, <i>Phill.</i>	C ?	-	-	H
" Lyelli, <i>W. Hind</i>	-	L	-	H
" primaeva, <i>Portl.</i>	-	H	-	H
" rudis, <i>M'Coy</i>	B	H	-	S H
" sulcata, <i>Phill.</i>	B L	-	-	H
" unioniformis, <i>Phill.</i>	-	H W	-	S
Lithodomus lingualis, <i>Phill.</i>	-	C ?	-	S
Myalina Flemingi, <i>M'Coy</i>	-	L	-	H
" peralata, <i>de Kon.</i>	-	L	-	H
Mytilomorpha (Goniophora) rhombea, <i>Phill.</i>	-	H	-	H
Parallelodon bistratus, <i>Portl.</i>	-	L	-	H
" cancellatus, <i>Mart.</i>	-	L	-	H
" decussatus, <i>M'Coy</i>	-	H	-	H
" fallax, <i>de Kon.</i>	-	H	-	H
" Fraiponti, <i>de Kon.</i>	-	H	-	H
" Geinitzi, <i>de Kon.</i>	-	L	-	H
" obtusius, <i>Phill.</i>	-	H	-	H
" reticulatus, <i>M'Coy</i>	-	L	-	H
" squamiferus, <i>Phill.</i>	-	H	-	H
" verneuilianus, <i>de Kon.</i>	-	C ?	-	H
Pinna flabelliformis, <i>Mart.</i>	C ?	I. W	-	S H
" spatula, <i>M'Coy</i>	-	L	-	H
Posidoniella pyriformis, <i>W. Hind</i>	-	L H	-	H
" vetusta, <i>J. de C. Sow.</i>	-	L	C ?	S H
Posidonomya Becheri, <i>Bronn</i>	-	-	S C W	S
Protoschizodus æqualis, <i>de Kon.</i>	-	L	-	H
" axiniformis, <i>Portl.</i>	-	H	-	H
" fragilis, <i>M'Coy</i>	-	H	-	H
" subtruncatus, <i>M'Coy</i>	-	H	-	H
" trigonalis, <i>de Kon.</i>	-	L	-	H
Sanguinolites angustatus, <i>Phill.</i>	-	L	-	H
" luxurians, <i>de Kon.</i>	-	H	-	H
" striatolamellosus, <i>de</i> <i>Kon.</i>	-	H L	-	H
" striatogranulosus, <i>Hind</i>	-	H	-	H
" subcarinatus, <i>M'Coy</i>	-	H	-	H
" tricostatus, <i>Portl.</i>	C ?	H L	-	S H
Scaldia benedeniana, <i>de Kon.</i>	-	H	-	H
" visetensis, <i>de Kon.</i>	-	H L	-	H
Solenomya primaeva, <i>Phill.</i>	-	L	-	H
" costellata, <i>M'Coy</i>	-	-	H	H
Tellinomorpha cuneiformis, <i>de Kon.</i>	-	H	-	H
GASTEROPODA.				
Aclisina sp.	-	W	-	S
Bellerophon hiulcus, <i>Mart</i>	S	C ?	-	S

	Lower or Castletown Limestone.	Poolvash Limestone.	Pool- donomya Feds.	Authority.
GASTEROPODA—continued.				
<i>ophon recticostatus</i> , Portl. -	C ?	-	-	S
<i>iphalus crotalostomus</i> , McCoy -	C ?	-	-	S
<i>opsis retrorsa</i> , Phill. -	-	C ?	-	S
<i>aema constrictum</i> , Mart. -	-	C ?	-	S
<i>rugiferum</i> , Phill. -	-	C ?	-	S
<i>scalaroideum</i> , Phill. -	-	W	-	S
<i>sulcatum</i> ? de Kon. -	-	C ?	-	S
<i>schilina acuta</i> , J. de C. Sow. -	W	H W	-	S
<i>rectilinea</i> ? Portl. -	C ?	-	-	S
<i>ptoma pileus</i> , Phill. -	-	L H	-	S H
<i>doma serrilimba</i> , Phill. -	-	C ?	-	S
<i>hisonia</i> ? -	C ? B	-	-	S
<i>opsis ampliata</i> , Phill. -	-	C ?	-	S
<i>plicistria</i> , Phill. -	S C	B W	-	S
<i>ia lirata</i> , Phill. -	-	C ?	-	S
<i>ceras angustum</i> , Phill. -	-	C ?	-	S
<i>trilobus</i> ? Phill. -	-	C ?	-	S
<i>schisma helicoides</i> , J. de C. Sow. -	B	B	-	S
<i>ovoideum</i> ? Phill. -	-	W	-	S
<i>otomuria</i> (<i>Luciella</i>) <i>eliana</i> , de Kon. -	-	C ?	-	S
(<i>Mourlonia</i>) <i>conica</i> ? Phill. -	-	W	-	S
(<i>Baylea</i>) <i>Léveillei</i> , de Kon. -	-	B	-	S
(<i>Ptychomphalus</i>) <i>sculpta</i> , Phill. -	-	-	C ?	S
(<i>Baylea</i>) <i>Yvani</i> , Lév. -	-	C ?	-	S
<i>ilia Puzo</i> , Lév. -	-	B	-	S
<i>ockia parallela</i> , Phill. -	-	B	-	S ¹
<i>arollus exaltatus</i> , de Kon. -	C ? B	-	-	S
<i>pileopsideus</i> , Phill. -	-	W	-	S
PTEROPODA.				
<i>laria quadrisulcata</i> , Sow. -	-	L	-	H
CEPHALOPODA.				
<i>oceras Breynii</i> , Mart. -	-	B C S L	-	S
<i>giganteum</i> , Sow. -	B L	L	-	S C ²
<i>Sowerbyi</i> , McCoy -	-	L	-	S
<i>sp.</i> -	L	L	-	S
<i>nautilus bistrialis</i> , Phill. -	-	B W	-	S
<i>cariniferus</i> , J. de C. Sow. -	-	L	-	S
<i>derbiensis</i> , Foord -	-	H L	-	S F
<i>subsulcatus</i> , Phill. -	-	C ? H L	-	S C. F
<i>oceras Gesneri</i> , Mart. -	-	L	-	S
<i>verneuillianum</i> , de Kon. -	-	S	-	S
<i>tes</i> (<i>Nautilus</i>) <i>complanatus</i> , Sow. -	C	-	-	M Coy ²
<i>bisulcatus</i> , de Kon. -	-	W	-	S
<i>discus</i> , Sow. -	-	H L	-	S

Determined by Mr. R. B. Newton.

² Brit. Pal. Foss. 1855, p. 557.

	Lower or Castletown Limestone.	Poolvaah Limestone.	Posi- donomya Beda.	Authority.
CEPHALOPODA—continued.				
Discites (Phacoceras) oxystomus, <i>Phill.</i>	-	C L	-	S
" planotergatus, <i>McCoy</i>	-	B H	-	S CT.
" sulcatus, <i>J. de C. Sow.</i>	C ? L	L	H ?	S
Ephippioceras bilobatum, <i>Sow.</i>	B L	-	-	S CT.
Glyphioceras crenistria, <i>Phill.</i>	-	B L	-	S
" implicatum, <i>Phill.</i>	-	S W	-	S
" micronotum ? <i>Phill.</i>	-	B	-	CT.
" obtusum, <i>Phill.</i>	B ?	-	-	S CT.
" sphaericum, <i>Mart.</i>	-	S	C ?	S
" striatum, <i>Sow.</i>	-	S	-	S
" truncatum, <i>Phill.</i>	-	B L S	-	S CT.
" vesica, <i>Phill.</i>	B	-	-	CT.
Gyroceras Luidi, <i>Mart.</i>	-	W	-	S
" ornatissimum, <i>de Kon.</i>	-	H	-	S
" sp. - - - - -	L	L	-	S
Nautilus globatus ? <i>Phill. (non Sow.)</i>	L	-	-	CT.
" sp. - - - - -	L	-	-	S
Orthoceras cf. acre, <i>Foord</i>	-	L	-	S
" affine ? <i>Portl.</i>	-	L S	-	S
" idoneum ? <i>de Kon.</i>	C ?	-	-	S
" cf. martinianum, <i>de Kon.</i>	-	L	-	S
" cf. saluum, <i>de Kon.</i>	-	L	-	S
" sulcatum, <i>Flem.</i>	-	L	H	S
" (several forms undeter- mined ¹).	L	L	-	S
Pleuromutilus ? scarlettensis, <i>Reed.</i>	W	-	-	Reed
Poterioceras cordiforme, <i>Sow.</i>	L	-	-	S
" fusiforme, <i>J. de C. Sow.</i>	-	C L	-	S
Prolecanites compressus, <i>Sow. (Goni- atites Henslowi, Sow.)</i>	B C L S W	-	-	S CT F
Solenocheilus dorsalis, <i>Phill.</i>	B	L	-	S CT.
" pentagonus, <i>Sow.</i>	B L	-	-	S CT.
Subclymenia evoluta ? <i>Phill.</i>	-	L	C ?	S CT.
Temnocheilus Cricki, <i>Foord</i>	L	-	-	CT.

¹ Mr. Law informs us that he obtained from the Poolvaah Limestone an Orthoceras 4 feet in length and 29 inches in circumference. This specimen lay flat in the limestone and was not distorted; it is probably an *Actinoceras*.

CHAPTER VI.

THE PEEL SANDSTONES.

Historical and General.

These rocks occupy a strip of the western coast about one and three quarter miles in length, extending from Peel north-westward to Will's Strand in a range of bold and picturesque cliffs averaging 50 to 60 feet in height. They consist of red and sometimes mottled sandstones with partings of red shale and with bands of pebbly conglomerate and lenticles of impure concretionary limestone. Fossils occur sparingly in the calcareous pebbles and concretions, consisting principally of fragments of corals in poor state of preservation, referable to the genera *Amphipora*, *Heliolites*, *Favosites*, *Cyathophyllum*, etc., all of which are unfortunately of wide range in time, along with stems of encrinites and a few imperfect shells (see p 276)

Unlike the Carboniferous Basement Conglomerate of the south of the Island, the pebbly layers in the Peel Sandstone contain little, if any, material derived from the Manx Slates. A few fragments of shale and grit may possibly have had this origin, but the majority of the pebbles are composed of quartz, quartzite, agate, sandstone, limestone, chalybite, and a porphyritic igneous rock which cannot be traced to any visible source within the Island.

Both eastward and westward the Sandstones are faulted off against the Slates; and their inland extension is hidden by a drift, so that except in one locality they are not visible at a greater distance than one quarter of a mile from the coast. The exception referred to occurs one mile inland, in the valley of the Neb at Glenfaba due south of Peel; but the exposure is very limited (p. 277), and considerable doubt exists whether it is continuous beneath the drift with the main outcrop on the coast, or whether, as Prof. Boyd Dawkins believes, it constitutes a small separate faulted inlier. For reasons given on a later page (p. 277) the former hypothesis has been adopted in the Survey map.

In the coast sections the sandstone is tilted steeply at an angle usually ranging between 30° and 50°, towards points between N. and N.W. Traces of folding are visible in one or two places, and the finer layers and calcareous bands are occasionally somewhat crumpled. A few small N. and S. faults, parallel to the boundary faults, are revealed in the cliff-section; and there are traces of other fractures, probably also of limited dimensions, along the strike of the beds, but none seems to be of structural importance except those which occur at the east and west boundaries.

The Peel Sandstone, being the only "freestone" of the Island, is noticed in all the old topographical descriptions. Of the geological writers, Berger, in describing its stratigraphical features, linked it with the Conglomerate of Langness.¹ Macculloch gave a full description of it and noted the occurrence of "thin beds of coarser grit and breccia." He considered that "in a geological view it must rank before the [Carboniferous] Limestone," and suggested that the calcareous strata following it were concealed by the sea.² Henslow added further details, and showed it on his map by the same colour as the Conglomerate of Langness.³ In the geological map which forms the frontispiece to Conybeare and Phillips' "Outlines of the Geology of England and Wales" (1822), it is however coloured and lettered as "New Red Sandstone," but there is no reference to the Isle of Man in the text.

Cumming in his first paper⁴ classified the Peel rocks, along with the Conglomerate of Langness, as Old Red Sandstone, stating that "it is of moderate thickness (not more than 300 feet) and covers from one to two square miles." He remarked that "the small patch of limestone which once existed on the surface of the Old Red Sandstone as it dips rapidly seaward, has some time since been wrought out,⁵ and it is difficult now to determine absolutely whether it belonged to the mountain limestone, or was merely a thin band of cornstone." Among the additional information on the subject contained in his later work is the following:—"The upper portion is greatly charged with carbonate of lime, and effervesces strongly with acids. It contains characteristic Devonian fossils such as *Favosites polymorpha*, though there is every probability that it passes very soon into the lower carboniferous series of the Island."⁶ No further details are given in regard to the fossils, nor are the specimens now to be found in the Cumming collection at the College at Castletown.

The occurrence of fossils in the Peel Sandstone was next noticed by Mr. J. [E.] Taylor, who remarked that "the imbedded pebbles are many of them of quartz but none of slate; while these are accompanied with limestone pebbles, in which may be seen fossils of an undoubtedly Silurian character. I have many a time chipped out fossil corals and portions of shells from these imbedded pebbles; and after a shower of rain, when the rocks are clean, they may be observed plentifully strewn among the fragments forming the Conglomerate."⁷ From the size of these

¹ Op. cit., p. 45.

² Op. cit., pp. 535 and 547-550.

³ Op. cit., pp. 493-4.

⁴ Quart. Journ. Geol. Soc., vol. ii., p. 320.

⁵ This is not quite correct, since a small portion of this limestone-band which could not be quarried without great danger, still remains overhanging the sea. (See p. 275.)

⁶ "Isle of Man," p. 200. The same statements are repeated in the "Guide," p. 159.

⁷ Trans. Manchester Geol. Soc., vol. iv. (1864), p. 77.

pebbles Mr. Taylor thought they could not have been carried far.

This statement as to the comparative abundance of fossils which are now quite rare, may perhaps be explained by the fact that the exposed surfaces of conglomerate are of limited extent, and weather very slowly; so that there may not have been time since they were ransacked by the earlier collectors for a fresh crop to appear. Mr. Taylor classified the deposit with the Langness Conglomerate which he regarded as forming "a sort of passage from the Carboniferous downward, rather than a representative of the Devonian formation."

The presence of fossils in the conglomerate-bands at Peel was observed again in 1875 by Mr. J. Shipman, who procured a good example of the fossiliferous limestone fragments from a quarry half a mile north of Peel.¹

Mr. Horne incorporated a description of the Peel sandstone in his paper on the geology of the Island published in 1874, correlating it, along with the Langness Conglomerate, with the Calciferous Sandstone Series of Scotland. As doubt has recently been thrown on this correlation, the following passages in which Mr. Horne states his opinion deserve careful attention, the author's personal knowledge of the Scotch rocks lending great weight to his conclusions.

"There is one important feature connected with this patch of red sandstones: it is the occurrence in them of some thin bands of cornstone, which strongly resemble the cornstones of the Calciferous Sandstone series in Scotland. . . . Cumming found in this cornstone a specimen of *Favosites polymorpha*, a Devonian form, from which he inferred that these beds are truly of Old Red Sandstone age. My colleague, Mr. R. Etheridge, Junior, F.G.S., suggests the probability of this specimen being the *Favosites polymorpha* (Phillips), which is the equivalent of *Favosites dubia* of Blainville, a true Devonian coral.² If this be true, then it only proves that some of these characteristic Devonian forms survived the close of the Old Red Sandstone period, and flourished in Lower Carboniferous times."

"From these data it is highly probable that the red sandstones, cornstones, and brecciated conglomerates in the Isle belong to the Calciferous Sandstone series. Lithologically, they resemble the members of the same series in Scotland. . . .

. . . . Not more than 40 miles off, on the Kircudbrightshire coast, there are beds belonging to this series which are in many respects identical with most of the Manx sandstones and breccias."³

No further additions were made to our knowledge of the deposits until 1894, when Prof. W. Boyd Dawkins published an

¹ Referred to in report of lecture to Nottingham Naturalists Society published in a local Nottingham paper in 1876. Mr. Shipman has kindly permitted us to examine the specimen (see fossil list p. 276).

² See Edwards and Haine, "British Fossil Corals," 1850, p. 216.

³ Trans. Edinburgh Geol. Soc., vol. ii., part iii., pp. 7-8.

important paper on the subject, in which he gave fuller details respecting the succession and thickness of the series than had hitherto been attempted, and claimed that they were of Permian age.¹ In later papers he re-affirmed his opinions, and stated that he had also recognised part of the series in a deep boring in the north of the Island. It will be shown, however, in the following pages that these views as to the age of the deposits can scarcely be considered proven; but before entering further into the discussion, it will be desirable to extract from the above-mentioned papers, the chief points of Prof. Dawkins' argument.

In his first paper on the subject, Prof. Dawkins states that the Red Sandstone series of Peel is 1,368 feet in thickness,² and consists of the following divisions, in ascending order.

1. The Red Sandstones forming the headland of Creg Malin, at the base of the series. "Their thickness is about 426 feet, calculated in the line of the dip as far as the southern end of Traie Fogog."

2. Reddish grey sandstones and irregular conglomerates, in the cliffs of Traie Fogog, with a thickness of 385 feet.

3. Brighter-coloured red sandstones and irregular red conglomerates, with sub-ordinate layers of red marl; 102 feet thick.

4. The calcareous conglomerates and breccias of the Stack series, about 455 feet thick, showing the following sequence in the east end of Traie Fogog.

"(a) Conglomerate composed of limestone pebbles embedded in a red sandy magnesian paste, about 10 feet.

"(b) Bright red marls with grey spots and grey calcareous concretions, about 10 feet 6 inches.

"(c) Red sandstone, faulted and slickensided, 4 feet 6 inches.

"(d) Conglomerate of the same character as (a), about 5 feet.

"(e) Red sandy marl mottled grey, about 12 feet.

"(f) Irregular layer of dolomitized limestone about 18 inches thick, with irregular calcareous concretions and conglomerate with red sandstone, 8 feet.

"(g) Bright red sandstone and calcareous conglomerates, and concretions of dolomite embedded in red paste, more than 20 feet in thickness.

"The conglomerates are composed of pebbles of hematite, marl, sandstone, jasper, cornelians, and anygdaloidal basic con-

¹ Trans. Manchester, Geol. Soc., pt. xxi., vol. xxii., pp. 1-7; also Rep. British Assoc. for 1894, p. 776.

² These measurements seem to be based upon calculations of the angle of dip and extent of visible outcrop; but as the base of the series is not seen, and the structure is less simple than at first appears, it may be doubted whether results obtained by the method are reliable. It will be noted that Cumming considered the total thickness to be "not more than 300 feet," but this must be an under-estimate (see p. 271).

taining chalcedony, and of carboniferous limestone. This last is more or less dolomitized, and presents traces of corals and shells *Euomphalus*?, *Spirifer*?, *Orthis*? or *Strophomena*?. The pebbles are imbedded sometimes in a bright red magnesian paste, and at others in a white calcareous base. The conglomerates are in places replaced by breccias of angular fragments. There are also dolomitic concretions which have been formed in a red sandy base, and are locally developed into irregular and highly-jointed layers of limestone, curiously acid-worn and honey-combed. This may be studied at the north-east end of Traie Fogog and in the Stack. The whole series is so irregular in its constitution that it is almost impossible to define the subdivisions. It agrees exactly with that so well described by Prof. Sedgwick at Barrow Mouth, near St. Bees."

*"The Evidence as to Permian Age."*¹

"These rocks may be divided into two distinct groups. First the Peel Sandstone series, which includes Nos. 1, 2 and 3 of the section, and presents a thickness of 913, and the calcareous conglomerates of the Stack series, which are 455, together a total of 1,368 feet. Their true base is concealed. The pebbles of Carboniferous Limestone in the conglomerates point to a post-carboniferous age, and the physical characters of both divisions are identical with those of the Permian rocks of the north of England, and more particularly with those of the Lake District, of the Vale of Eden, and Barrow Mouth, described by Sedgwick, Harkness, Binney, Eccles, and Nicholson.

"The Peel Sandstones are the equivalents of the Rot-todt-liegende of the Continent and the Lower Permian Sandstones of St. Bees' Head and the Vale of Eden. The Stack Conglomerates and Breccias represent the base of the Magnesian Limestone series of the Upper Permians and the upper (rotten) 'Brockram,' or conglomerate, of Mr. Binney. The thickness of the Permian rocks of the Isle of Man is more than 1,368 feet. In Hilton Beck, in the Vale of Eden, it is more than 2,000, according to Nicholson.

"The presence of the calcareous rocks of the Stack series resting upon the thick Peel sandstones renders it impossible to classify the series with the Triassic strata, in which the conglomerates are below and the sandstones above. The Permians of Cultra, on the south side of Belfast Lough, described by Binney, present a similar relation of the conglomerate to the Rot-todt-liegende. It is therefore clear that north-eastern Ireland, the northern part of the Isle of Man, and the area of the Lake District including the Vale of Eden, were parts of the same Permian marine basin, in which, as it approached southern Lancashire, the waters gradually were more highly charged with mud, the calcareous element being conspicuous in the one, and being replaced in the other by thick accumulations of marl."

¹ This paragraph is quoted in full.

The same paper contained an account of the discovery of Triassic rocks in the deep borings in the north of the Island, a discovery which no doubt had considerable influence upon Prof. Dawkins' opinion as to the age of the Peel rocks.

In a paper in the following year, Prof. Dawkins gave further details of the boring at Ballawhane (which had in the interval been carried through the Triassic Rocks), and stated that it had revealed the Triassic Sandstone, equivalent to the St. Bees Sandstone of Cumberland, resting unconformably on Permian rocks of the Stack Series which were faulted off downwards against Carboniferous Limestone.¹

His reading of the Ballawhane section was as follows:—

" Boulder Drift sands, gravels, and clays -	171 ft.
Triassic Sandstone, red and grey -	373 „ 2 in.
Permian Marls and Sandstones of the	
Stack Series -	136 „ 2 „
Carboniferous Limestone, grey and red,	
with crinoids -	37 „ 10 „

"In this section the Triassic Sandstone cores prove a dip of 10°, while the Stack Series below have a dip of from 30° to 40°. The absence of the Peel Sandstones proves that the Permians are faulted against the Carboniferous Limestones. The Triassic Sandstone probably belongs to the Lower or Bunter Series." (Rep. Brit. Assoc.)

If this interpretation of the Ballawhane section had been correct, it would, of course, have gone far towards establishing the Permian age of the Peel rocks. But, on behalf of the Geological Survey, I had made a careful examination of the cores while the boring was in progress, and had secured a set of specimens, now preserved at the head-office of the Survey, which afforded clear evidence of the Lower Carboniferous age of the supposed Permian rocks; and I am permitted by Prof. Dawkins to state that after a recent inspection of these specimens he no longer regards the strata between 544 and 680 feet as Permian, but agrees with me that they form part of the Lower Carboniferous series. There is, indeed, little or no resemblance between any of the rocks of this boring or of the other borings and the Peel strata, so that no direct correlation is possible between them.

It follows that the deductions which Prof. Dawkins has drawn from the supposed break between the Permian and Trias² in this section, are untenable so far as concerns the Isle of Man.

¹ Trans. Manchester Geol. Soc., pt. vi., vol. xxiii., p. 147; and Report British Assoc. for 1896, p. 777.

² "The Permians had been lifted up above the sea and worn down into a marine floor, composed of highly inclined strata before the Triassic age. On this floor the Triassic Sandstone was accumulated. This point, so clearly proved in the section, is the clue by which the Permian and Triassic geology of the Lake District, now so inadequately represented in the maps of the Geological Survey, may be unravelled." Trans. Manch. Geol. Soc., pt. vi., vol. xxiii., p. 152.

Although no rocks directly comparable to the Peel Series have been reached in any of the borings, probably because the equivalents of the series lie deeper than the lowest strata touched, the sections afford two strong arguments against the Permian age of the Peel Series. In the first place, in two of the borings the New Red rocks, from the St. Bees Sandstone downwards to their base, were passed through in normal sequence and included true "Permian" strata, resembling those of the opposite mainland but differing both in lithological features and in stratigraphical arrangement from the Peel Series. And secondly, in three of the borings the Carboniferous Limestone series was found to include much sandstone, usually red in colour, which, though not indeed particularly resembling the Peel Sandstone, at any rate shows that the conditions in the basin of deposition were favourable for the production of arenaceous rocks in Lower Carboniferous times. All these Carboniferous strata, moreover, possessed the high dip of the Peel rocks, while the overlying New Red group invariably lay unconformably upon them at a low angle (see p. 291).

Thus the evidence of the borings goes far to disprove Prof. Dawkins' contention. The other grounds on which he has rested his argument are (1) that "the physical characters . . . are identical with those of the Permian rocks of the north of England, and more particularly with those of the Lake District, of the Vale of Eden, and Barrow Mouth"; and (2) that pebbles of "Carboniferous Limestone" occur in the conglomerates.

With regard to the first point, which refers to the general lithological aspect of the series, it has already been noted that Mr. Horne considered that these rocks bore a close resemblance to the Lower Carboniferous (Calciferous Sandstone) series of the Kircudbrightshire coast; and the supposed Permian aspect has likewise failed to impress several other observers conversant with New Red rocks. From my own examination of the coast-section at Barrowmouth south of Whitehaven, referred to by Prof. Dawkins, I can bear testimony to the close resemblance of the "Permian" Brockram-conglomerate here with that revealed in the deep borings at Knock-e-Dooney and Ballagenney, but failed to detect any resemblance with the Peel Series; and the same result attended my investigation of inland sections of Permian rocks in the Eden Valley.

The second argument is one on which Prof. Dawkins lays much stress. It may be granted that some of the pebbles of limestone which occur sparingly in the conglomeratic bands at Peel may be of "Carboniferous Limestone," though the evidence is still unsatisfactory. In Prof. Dawkins' paper it is mentioned that they contain "traces of corals and shells, *Euomphalus*?, *Pirifer*?, *Orthis*?, or *Strophomena*?" Since his paper was published, Prof. Dawkins has collected further specimens which he has kindly allowed me to examine. These include individuals of a small finely ribbed *Chonetes* identified by Prof.

Dawkins as *Chonetes Buchiana*, and portions of a small trilobite supposed to be of Carboniferous age. My own collection from the calcareous and conglomeratic beds at Lhooby Reeast includes some determinable corals of wide range in time and some indifferently preserved shells, which point to an Upper Devonian or Lower Carboniferous origin; but these are contained in a somewhat gritty calcareous matrix of concretionary character and may, I think, be contemporaneous. Their whole facies is very different from the fossils of any Carboniferous Limestone which is known to occur in the Island (see p. 276). In the sections a little farther south there are isolated pebbles of encrinital limestone in beds which are not markedly calcareous; with these are associated fragments of soft red shale and sandstone such as might have been derived from any of the shaly and sandy beds of the Peel Series, which I am inclined to regard as evidence of contemporaneous erosion of slightly older beds, already partially consolidated, while the newer beds were being deposited; and the same explanation will, I think, hold good for the limestone pebbles.

Cumming suggests that these rocks were accumulated as a shore deposit of the Lower Carboniferous sea, while limestone was being formed at a slightly greater distance from the land; and under such conditions the presence of fragments of the calcareous rock, even if these are proved beyond question to contain Lower Carboniferous fossils, does not necessarily signify the Post-Carboniferous age of the series. Conglomerates made up largely or wholly of fragments of the same general age as the pebbly bed have now been recognised at various horizons throughout the geological scale, being perhaps commonest among calcareous sediments and stiff coherent clays, which soon consolidate sufficiently to undergo short transportal. The term "Intra-formational Conglomerate"¹ has been applied to breccias of this character by American geologists. The shore-breccia sometimes surrounding coral reefs might be cited as a modern illustration of the structure.

For an analogous example of an admixture of "contemporaneous" pebbles with others of older date, attention may be directed to the conglomerate of Lower Carboniferous age, interbedded with limestones and shales, which is exposed on the opposite coast of the Irish Sea, at Rush, co. Dublin, wherein blocks and pebbles of limestone belonging to the Carboniferous series are mingled with fragments derived from Silurian and other sources.² In the Lower Carboniferous rocks of Anglesey, also, pebbles of Carboniferous limestone occur in sandstone interbedded with the limestone³; and in Derbyshire and

¹ See C. D. Walcott, "Palæozoic Intra-formational Conglomerates," Bull. Geol. Soc. America, vol. v. (1894), pp. 191-198.

² See Mem. Geol. Survey of Ireland on Sheets 102 and 112, pp. 61 et seq.

³ E. Greenly, Quart. Journ. Geol. Soc., vol. lii. (1896), p. 629.

Staffordshire a "beach-deposit" of rolled shells and limestone fragments forms part of the Carboniferous Limestone series.¹

One of the strongest points in the argument against the Permian age of the Peel rocks is that the true Permian breccia or "Brockram" found at the base of the Red Rocks, and in no other part of the series, in two of the northern borings had nothing in common with the Peel conglomerates (see pp. 285, 288). It contained fragments of undoubted Carboniferous Limestone in abundance, both large and small, thoroughly dolomitized on the exterior and often partially hollow in the interior, like the limestone inclusions in the Permian Brockram of the mainland, but quite unlike the Peel pebbles which are always solid, horny in texture, and only slightly dolomitic; and the other materials of this Brockram were also totally unlike the assemblage of pebbles of the Peel conglomerates. Other data bearing on this question will be found in the subsequent descriptions, and in the next chapter dealing with the concealed strata of the northern plain. Meanwhile I think that sufficient evidence has already been adduced to show that the Permian age of the Peel Sandstones has not been proven and that they are probably not newer than Lower Carboniferous.

With regard to the thickness of the series, there must necessarily be much uncertainty, in view of the lack of more definite information as to the base and the inland extent of the rocks. The continuously high dip of the rocks in the coast sections shows that the thickness must be considerable; but the many small faults and the decrease in the angle of dip which may be observed in the exposures most remote from the cliff lead me to think that Prof. Dawkins' estimate of 1,368 feet *for the beds actually seen in the coast-strip* is excessive, though if the series extend so far inland as I have supposed its aggregate thickness, including the concealed portion, may possibly be as much as this or even more. Cumming's valuation of "about 300 feet"² is in any case too low. In the eastward or inland prolongation it is unlikely that the steep dip of the coast-sections will be retained, unless accompanied by folding or overthrusting. That the series everywhere rests directly upon the Manx Slates is almost certain; but the character of the junction has not been proved. When we remember the many signs of lateral disturbance in the Carboniferous rocks of the southern basin, and in those of the same age which underlie the northern plain, the possibility that the Peel series may have been pushed forward upon the slopes of the old massif, and may have an overthrust plane at its base, deserves consideration, especially as the rocks themselves in places bear traces of compression and crumpling. In fact the more closely one studies the stratigraphy of the

¹ J. Barnes and W. F. Holroyd, Trans. Manch. Geol. Soc., vol. xxv. (1897), pp. 119-125; and *ibid.*, pp. 181-184, and p. 308. See also H. H. A. Bemrose, Proc. Geol. Assoc., vol. xvi. (1899), pt. 4, p. 174.

² "Isle of Man," p. 240.

Island the more strongly does one become impressed with the idea that lateral movement at different stages has been the dominant factor in the arrangement of the strata,—first crumpling up the older rocks into a central ridge or massif, and long afterwards driving in the Carboniferous deposits upon the more or less rigid core. We have already seen that the later of these movements took place after the deposition of the Lower Carboniferous rocks but before the accumulation of the New Red rocks of the northern plain, which are practically undisturbed. Hence the evidence of disturbance in the Peel Series affords another argument in favour of the Pre-Permian age of these rocks (see also p. 291).

Detailed Description.

ST. The boundary fault which brings in the Peel Sandstones on the east is
RIONS. clearly exhibited at Will's Strand (six inch, Sheet 6). In the cliff at the

FIG. 74. *Section of crumpled bedding in calcareous sandstone, on beach at north side of White Strand.*

Depth 2 feet.



south side of this recess, rather thickly bedded red sandstone of fine grain, with marly partings, is let down against crushed slate by a dislocation which fades towards the west at about 70°. Heavy slips of drift obscure the cliff to the northward, but the fault may be traced at low water across the shore, striking a few degrees west of north. Towards low tide the hade of the fault becomes much less steep and suggests an overthrust, being in places as low as 30°. The crushed and stained red and greenish slate has at this place the appearance of passing beneath the sandstone, and this appearance is probably the basis of Cumming's statement that "near Lhergydhoo the Old Red Conglomerate or Sandstone is seen to rest unconformably on the upturned edges of the claret-coloured schists."¹ The dip of the sandstone is steeply (40° to 50°) to N.N.W. or nearly in the direction of strike of the fault.

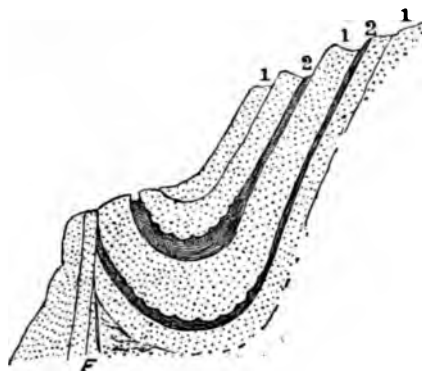
In the headland to the southward of Will's Strand, the sandstones are considerably disturbed, and there seems to have been some lateral movement along a sharply defined plane at the foot of the cliff. Between this place and White Strand, 400 yards farther south, some pebbly and

¹ Guide Book, p. 113.

calcareous bands make their appearance, which Prof. Dawkins recognises as belonging to his "Stack Series." The distinction between this series and the "Peel Sandstones" of the same author is, however, ill defined, the field-evidence suggesting that the calcareous and conglomeratic bands are in this quarter more or less lenticular, and irregularly dispersed among the sandstones. There is nothing in these sections comparable to the thick cornstone of Lhoob-y-Reeast presently to be described. The curious and suggestive structure of some of the thin calcareous layers among the red shaly beds as shown in the foregoing figure (Fig. 74) implies that there has been greater disturbances in these strata than one would suspect from a cursory examination, and raises the suspicion that some of the calcareous beds which are now lenticular or nodular may originally have occurred as continuous bands.

Besides the above-mentioned nodular or lenticular calcareous seams there are, in this quarter, true pebbly layers containing, along with fragments of chalybite, agate and other rocks, a few pieces of impure

FIG. 75. *Cliff-section in Peel Sandstone at north side of White Strand. Height about 20 feet.*



1. Courses of red sandstone, showing curious swellings on under surface in trough of fold. Diagrammatically rendered.

2. Shale partings.

F. Fault $\frac{1}{2}$, with crushed rock in vicinity

limestone, in one of which encrinite-stems were embedded; and in another instance a single detached ossicle of the same fossil was seen in the pebbly band. As at Lhoob-y-Reeast, these bits of limestone occasionally show faint indications of coral structure.

In the bluff at the northern extremity of White Strand a sharp synclinal plication is revealed, which produces a striking effect upon a two-feet bed of sandstone overlying a few inches of shale, the under surface of the sandstone in the trough of the fold being rucked up, as roughly shown in Figure 75, into a pillowy structure or "knobby-side," like that on a larger scale already described in the Manx Slates (see p. 75).

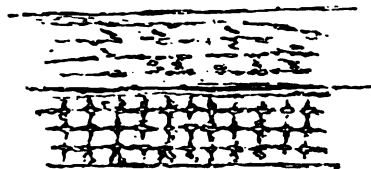
On the shore at high-water mark in this locality, some thin calcareous shaly layers which intervene between rather thick-bedded sandstones above and pebbly calcareous strata below, are crumpled, partially brecciated, and cut by two parallel planes along which there appears to have been a certain degree of lateral displacement. Similar indications of pressure and disturbance are repeated in the sections farther south; and I regard them as affording indirect evidence of the age of the series, since in the deep borings in the north wherever the Lower Carboniferous rocks were pierced

they showed signs of similar or greater disturbance, while in the overlying Triassic and Permian strata such indications were absent.

In the middle of White Strand the red sandstones dip towards N. or N. 10 E., at from 15° to 25°; but in the headland to the southward they are interrupted by two or three fault-like breaks, striking approximately N. to N.N.W., possibly with a westerly downthrow, beyond which the dips change to N.N.W. or N.W. Along one of these fractures a short adit has been driven into the cliff. Similar and parallel fractures recur at intervals throughout the range of the sections, but none seemed individually of sufficient importance to be worth showing on the published map. Their cumulative effect may, however, be of some consequence; and they must in any case render difficult and uncertain the calculation of the thickness of the rocks from the dip and width of outcrop (see foot-note p. 266).

Between White Strand and *Cass Strooan* (the more southerly of the two little streams draining to the coast quarter of a mile farther south), the cliffs and foreshore are occupied by fine red or mottled sandstones in thickish beds, with shaly partings and a few thin lenticular bands of conglomerata. The sandstones are sometimes cross-bedded, and sometimes possess ripple marked surfaces. The mottling seems to be due to the semi-concretionary segregation of the small quantity of lime contained in the rock. In

FIG. 76. *Structure in Peel Sandstone at foot of cliff below quarry on south side of Cain's Strand.*



Two beds of red sandstone, 4 feet thick, with yellow concretions tending in the lower bed to a linear arrangement both horizontally and vertically.

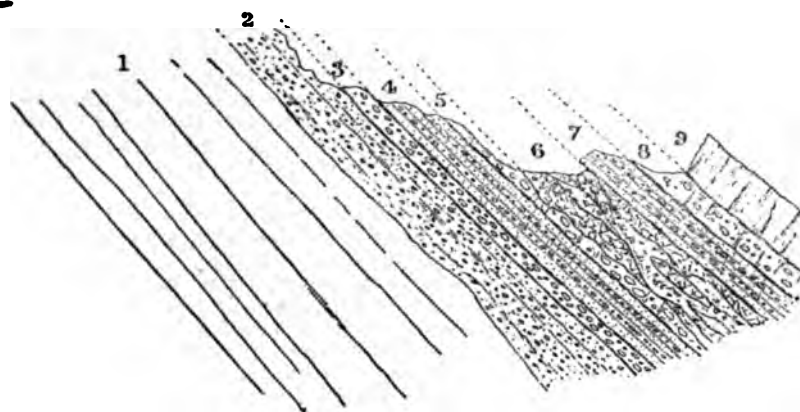
places the structure presents a curious reticulate arrangement of intersecting planes, as shown in the above figure (Fig. 76), giving rise on weathering to the "honey-comb" appearance commented on by Prof. Dawkins.

At *Cain's Strand* the sandstone has been quarried in the cliff. The deep ravine which extends backward from this place to the highroad, a quarter of a mile to the east, seems to be cut entirely in drift, the present stream evidently following the course of a pre-glacial drift-filled hollow. But *Cass Strooan*, 150 yards farther south, reveals the sandstone for at least 250 yards backward from the cliff; and in this valley a shaft has been sunk in search of coal in the sandstone 150 yards from the shore (see p. 279). To the eastward of the highroad the last-mentioned stream occupies a shallow trench obscured by alluvium; but at one place, 230 yards south-east of the road, it exposes traces of red rubbly material which may be either the weathered top of the sandstone, or a local drift derived from it.

On the coast S.W. of *Cass Strooan* we find thinly-bedded lenticular sandstone with calcareous concretions and partings of red shale, for the most part dipping at about 40° towards N.W., the dip slopes, undercut by the sea, forming a somewhat treacherous cliff. At *Lhoob y Reeast* (6-inch, Sheet 9), 400 yards E. of The Stack, a jutting forward of the coast-line brings in fossiliferous calcareous strata overlying shaly sandstones; and near this place is the section which is by far the best for fossils in the whole range of exposures. The old lime-kiln mentioned by Cumming still exists at the top of the cliff in the little recess 200 yards W. of *Lhoob y Reeast*. Immediately below it are dip-slopes of pebbly calcareous grit, and this was originally overlain by a band of limestone, which has been

stripped off to supply the kiln except at one spot overhanging the sea, where further operations would have been dangerous. A rough chemical examination of specimens of this limestone and of the "pebbles" or concretions in the conglomeratic beds associated with it, was made by my colleague Dr. Pollard, and showed that they consisted essentially of carbonate of lime with only a little magnesia. It is on these slopes that the fossils may be obtained, and though the surfaces are uncomfortably steep they are not dangerous to anyone accustomed to cliffs. The following figure shows the section at this place.

FIG. 77. *Cliff-section below the old lime-kiln 200 yards west of Lhoob y Reeast near Peel.*



- | | |
|---|----------------|
| 9. Pale nodular gritty limestone ; nearly all quarried away - - - - - thickness | 3 feet. |
| 8. Lenticular pebbly cornstone with palish red limestone concretions - - - - - | 1½ " |
| 7. Sandy and gravelly band, with calcareous cement and small fragments of limestone : some corals - - - - - | 2 " |
| 6. Lenticular patches of coarse and fine subangular conglomerate with limestone pebbles, and also calcareous concretions and cement ; fragments of encrinites and other fossils - - - - - | 3 " |
| 5. Pale red nodular limestone band - - - - - | 3 to 6 inches. |
| 4. Red sandstone, grit and fine gravelly conglomerate : some fossils - - - - - | 2½ feet. |
| 3. Pebbly band with pebbles and also concretions of limestone : fossils : among the pebbles are agate, quartzite, vein quartz, sandstone and chert - - - - - | 1 foot. |
| 2. Red sandstone interbedded with fine gravelly conglomerate, less calcareous than above : fossils, — polyzoa and some detached fragments of corals - - - - - | 3 to 6 feet. |
| 1. Sandstone, etc., not exposed in this section. | |

The fossils are best seen when the rock is wet, as noted by Mr Taylor (p. 264), but at all times it needs a close search to discover them, as they are both rare and inconspicuous. By far the most abundant are the corals, and in fact the majority of the limestone fragments show traces, more or less obscure, of coral structure. Some are clearly pieces broken from larger masses and partially eroded, but others are intermingled with the red grit and appear as though they might be proper to the bed. Shells though not entirely absent are extremely rare, and very poorly preserved. Like the corals, they occur sometimes in a rolled condition in the gritty

calcareous matrix of the bed, and sometimes in pebbles of limestone. In the following list of the fossils of the Peel Series the specimens, with one or two exceptions, were all obtained from this locality. The determinations have been made by Messrs G. Sharman and E. T. Newton.¹

LIST OF FOSSILS FROM CALCAREOUS CONGLOMERATE IN THE PEEL SANDSTONE BETWEEN THE STACK AND LHOOB Y REEAST.

Corals.—Alveolites?

Amplexus (near to tortuosus).

Cyathophyllum sp.

Favosites fibrosa? *Goldf.*

" Gothlandica? *Goldf.*

" ? (with distinct septa).

Heliolites tubulata, *Lonsd.*

Monticulipora tumida? *Phil.*

Pachypora (Favosites) cervicornis, *de Blainv.*

Brachiopoda.—Chonetes?

Orthis sp.

Productus?

Spirifera sp.

Besides the above the following specimens have been found :—Sponges? Polyzoa, Emericinella fragments, a large and a small Gasteropod. A specimen collected by Mr. J. Shipman in a quarry near Peel, and kindly presented to the Survey, contained the following forms :—Favosites?, Fistulipora, Monticulipora, and Syringopora.

From Lhoob y Reeast the set of strata above-described is prolonged south-westward to The Stack, though the thicker cornstone bands seem to be lenticular and not continuous in the same plane for many yards. These conglomeratic bands and cornstones, as Prof. Dawkins has shown, appear to overlie the sandstones, and thus form the highest visible portion of the Peel Series. A line of crushing and fracture runs E.N.E., with the strike of the beds, along the foot of the cliff between Lhoob y Reeast and The Stack, and the arrangement of the confused bedding in the central mass of The Stack suggests a sharp fold, though it may possibly be due to bold false-bedding only.

A band of pale impure concretionary limestone several feet thick has been quarried in a little gully in the cliff (above "Cave" of the six-inch map) 80 yards S. of the Stack. This may represent the thick cornstone of Lhoob y Reeast, but if so, it has probably been shifted slightly southward by small faults; a similar, or perhaps the same, band is revealed at low water at the bottom of the cliff, 80 or 90 yards farther S., at the next "Cave" marked on the six-inch map. Some dyke-like veins of dolomite and calcite, referred to by Macculloch, traverse the strata between these places. Beyond the Stack the more southerly trend of the coast cuts out these calcareous strata and brings the underlying beds into the cliff, the prevalent dips being still about N.N.W. at 40° to 50°. At Traie Fogog 350 yards S.W. of The Stack, the rocks are chiefly thin-bedded and current-bedded red and mottled sandstone including pale yellowish calcareous concretions, interstratified with partings of red shale or marl and bands of fine conglomerate or breccia containing subangular fragments of red shale and sandstone together with limestone, chert, jasper, agate, chalybite, etc. At Creg Malin, 200 yards farther S.W., where the cliff-sections cease abruptly, the red sandstones are more thickly bedded and the shale partings and conglomerate lenticles correspondingly less prominent; the rock has been extensively quarried at this place in the steep bluff overlooking the strip of Raised Beach on which stands the lower part of the town of Peel.

The depression between Creg Malin and the high slate ridge of Peel Hill (p. 146) has been a Pre-glacial channel of erosion, during a period of elevation in which the solid rocks have been cut down below sea level. This hollow has afterwards been partly filled with thick drift. The faulted junction of the Peel Sandstones with the slates occurs in the hollow and is thus com-

¹ Prof. Boyd Dawkins has recently shown that many of the fossil in his collection are Ordovician forms: see postscript at end of chapter, p. 279.

pletely hidden. The foundations for the sea-wall in the eastern part of Peel Bay revealed only sand and shingle¹; and the submarine work in connection with the deep water extension recently made to the Pier running eastward into the Bay from St. Patrick's Isle showed that the sea-floor at the mouth of the channel was occupied by glacial deposits (see p. 442). Hence the position and direction of the boundary fault at this point must remain more or less conjectural. On the Survey map, the line adopted is the prolongation of the fault visible at the inland exposure of the Conglomerates at Glenfaba Bridge, described in the next paragraphs. It differs from the boundary chosen by Prof. Dawkins for the purpose of his sketch-map,² but has the practical advantage of making the one known fault serve, without the introduction of a second about which nothing is known.

Inland Extension of the Sandstones.

The inland boundary of the Sandstones is everywhere drift-covered, and the available information is for the most part insufficient to fix its limits within $\frac{1}{2}$ or even $\frac{3}{4}$ of a mile. That the series extends up from the coast to the Kirk Michael highroad is certain; but its supposed extension beneath the broad strip of drift-covered low ground to the south-eastward of the road, as shown on the published map, is hypothetical and open to much doubt, being based only on the shape of the ground (which is smooth and low in this tract, but is broken by hillocky rock-features where the Manx Slates rise through the drift along its margin), and on the presence of the conglomerate so far inland as Glenfaba Bridge in the Neb Valley.

There are extensive quarries in the sandstone near the coast at Ballaquane, 300 to 400 yards east of Creg Malin, in which the direction and amount of dip agrees with the coast-sections, the rock being rather fine grained and arranged in lenticular beds bounded by layers of coarse shaly conglomerate. Similar rock with a rather lower dip, is exposed on both sides of the high road north of Ballaquane House. QUARRIES
NEAR PEEL

The exposures around Glenfaba and Raggatt, nearly a mile south of Peel, now alone remain to be described. Prof. Dawkins considers these to form small faulted outliers, separated from the main mass by a concealed strip of slate $\frac{1}{2}$ mile in width; but his version of the ground does not take into account the fault striking N. 12° to 15° E. which is clearly exposed under Glenfaba Bridge; and while I would readily acknowledge the possibility of there being two parallel faults downthrowing in opposite directions between the main outcrop and Glenfaba, as represented by Prof. Dawkins, it seems preferable, as already stated, in the absence of any definite evidence to the contrary to simplify the reading by adopting the prolongation of the Glenfaba fault as the continuous western boundary of the sandstones, thus extending the main mass of these rocks farther inland than Prof. Dawkins would allow. GLENFABA
BRIDGE

Above and below Glenfaba, the river Neb flows across flats of ancient alluvium resting on a floor of drift; but at this place, its valley is constricted for 200 to 300 yards into a narrow rocky ravine which probably marks a local divergence of the present river from the channel of its preglacial forerunner. Slate is revealed in both banks of this ravine below the bridge, and also in the bed of the stream; but the western buttress of the bridge stands on pebbly conglomerate, which is faulted off suddenly against the slate in the steep bank immediately below. Similar conglomerate is exposed in the shallow railway cutting on the S.E. side of the bridge, adjacent to Glenfaba Mills, and may also be present, in a much overgrown and drift-covered condition, on the high river bank under the N.W. side of the high road. The direction of the fault, as given above, can thus be fixed within a few degrees. These exposures of the conglomerate are much weathered and too limited to show much character, but the rock differs

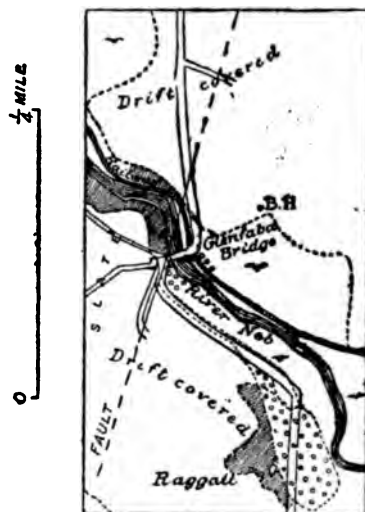
¹ I am indebted to Mr. T. Corrin of Peel for this information, which was confirmed by Mr. Woods, who had personal charge of the work.

² Op. cit., Trans. Manch. Geol. Soc., vol. xxii., pt. xxi.

in many respects from that of the coast, being apparently largely made up of material derived from the Slate series, as we might expect to find in beds low down in the succession, if not actually at its base. The dip is scarcely recognisable, but is not the same as on the coast; in the railway cutting it appears to be on the whole easterly, at an angle of over 50° .

The highroad from Peel after crossing Glenfaba Bridge turns sharply to E.S.E. and continues for 270 yards along the edge of an alluvial flat bordering the river; and then turning again southward, at Raggatt, ascends a low slope and leaves the main valley. On this slope, red sandstone and pebbly conglomerate, closely resembling those of the Peel sections, are exposed by the road-side for about 100 yards, and appear to have been quarried in a garden lying to the E. of the road, where the indications denote a gentle northerly dip. On the opposite side of the road, in the

FIG. 78. *Sketch-map of the valley of the River Neb around Glenfaba Bridge, showing position of outcrops of slate and conglomerate. Scale: 6 inches = 1 mile.*



Conglomerate indicated by circles.
Slate indicated by oblique shading.
B. H. Borehole.

bed of a streamlet which runs behind the farmstead of Raggatt, decomposed slate is seen towards the top of the slope, and red conglomerate 20 or 30 yards lower down, suggesting that we have in this vicinity the unconformable overlap of the base of the conglomerate upon the older rocks. Slate has also been reached in an old mining trial on the slope 40 or 50 yards to the W. of the road. Again, at the sharp bend in the bed of the Neb 50 yards E. of Raggatt, red sandstone and conglomerate crop out in the west bank and in the bed of the stream; and decomposed slate may be seen 30 yards farther up-stream when the water is low. The position of these exposures is shown on the accompanying ground-plan of the valley between Glenfaba and Raggatt.

About thirty-five-years ago companies were formed to search for coal in the vicinity of Peel, and several borings were made, respecting which it is unfortunately difficult now to gain definite information. The only documentary evidence which we have been able to obtain, is the journal of a boring

"near Peel," given on 587, for which we are indebted to Messrs. Craine Bros. of Liverpool. It indicates Drift, 37 feet thick; resting on Red Sandstone, 50 feet 3 inches thick; on "grey fakes," "fireclay," "whinstone," etc. (evidently the Slate series), 294 feet 3 inches; the total depth of the boring being 381 feet 6 inches. We have found no means of identifying the site, but whether the record refers to the vicinity of Glenfaba, or to one of borings which were made to the north-eastward of Peel, it is of importance in demonstrating that the Red Sandstones are directly underlain by rocks of slaty type.

The approximate site of another of these borings is shown in the preceding plan (fig. 78). From one source I learnt, on hearsay evidence, that "broken-up slate such as is worked for bricks at the brickyard above the harbour" was met with in this boring; and from another source, that clay, sand and gravel extended downward to 90 feet, with 2 feet of grey sandstone at 120 feet, and blue fireclay (slate?) down to 150 feet.

A third boring was made $1\frac{1}{2}$ miles farther N., near the northern termination of the Sandstones, in the N.W. corner of the field containing the old earth-works marked **The Court** on the map, 200 yards south of Ballagyr farm. I was informed by the occupant of the adjoining farm, who remembered the boring being made, that it went through "shingle" into "blue clay" but did not strike the red sandstone. Another informant, however, who claims to have had a direct interest in the work, was positive that the red sandstone was met with; and upon the merits of conflicting evidence of this kind, it is of course now impossible to decide.

[POSTSCRIPT, AUG., 1902.—While the final proofs of this Memoir are in hand, Prof. W. B. Dawkins has communicated to the Geological Society of London two further papers on the subjects dealt with in this and the next chapter, under the titles—1, "The Red Sandstone-Rocks of Peel, Isle of Man;" and, 2, "The Carboniferous, Permian and Triassic Rocks under the Glacial Drift in the North of the Isle of Man." In these papers Prof. Dawkins reiterates his conviction that the Peel Rocks are of Permian age. At the time of writing, the full text of these papers has not been published; but so far as I can judge from hearing the reading of the papers, and from the printed abstracts (Abstr. of Proc. Geol. Soc., May 28, 1902, No. 762), the arguments on this point which I have employed in the foregoing chapter, and my opinion therein expressed, remain unimpaired; and the text of the chapter has therefore been allowed to stand unaltered.

Great interest, however, attaches to Prof. Dawkins' statement that several of the fossils from the limestone-fragments in the Peel Rocks have been identified with species found in the Keisley Limestone, which is of *Ordovician* age; but others are still claimed as Carboniferous species.

The second paper contained an account of all the borings described in the next chapter.]

CHAPTER VII.

THE STRATA UNDERLYING THE DRIFT OF
THE NORTHERN PLAIN.**Historical and General.**

The opinion had long been entertained by geologists that rocks of Carboniferous age were likely to exist beneath the drift-covered northern plain of the Island. Thus, in 1848 Cumming remarked, "it is very reasonable to conclude that the basest edge, both of it [*i.e.*, of the Peel Sandstone] and of the different beds of the superior limestone, curves round to the northwards and passes under the northern area of the Isle of Man"; and he even suggested that borings should be made to seek the limestone which he thought might occur at from 60 to 100 feet below the surface along the northern edge of the Curragh. To this suggestion he added the following foot-note:—"In the year 1839 borings were made for coal at the Craig near St. Jude's Church; the following is stated to have been the result; 5 feet sand, 27 feet blue marl, 2 feet gravel, 27 feet blue marl, and then sand. The boring was not proceeded with any deeper."¹ Again, in an editorial note in the reprint for the Manx Society of Sacheverell's "Account of the Isle of Man" (Douglas, 1859), in discussing the probability of the occurrence of coal, Cumming stated that it was "just possible, though far from probable," that some of the higher portions of the Carboniferous series might underlie the northern plain: (p. 17 of reprint). The same conjecture was made by Mr. J. D. Kendall in 1883, in discussing the westward submarine extension of the Whitehaven Coalfield.²

Besides the Craig boring mentioned by Cumming, other attempts to find coal seem to have been made in the plain about the middle of last century (see p. 558); and one of these, in the vicinity of Cranstal, is reported to have reached the base of the drifts. But it was not until 1891, when Messrs. Craine Bros. of Liverpool commenced the systematic exploration of the northern extremity of the Island, that any definite information regarding the buried rock-platform was forthcoming. The first descriptions of their investigations were published by Prof. W. Boyd Dawkins in 1894 and 1895,³ who gave the record of three borings which

¹ "Isle of Man," p. 210.

² "The Structure of the Cumberland Coalfield," Trans. N. of Eng. Instit. of Min. Engineers, vol. xxxii., p. 356.

³ Trans. Manchester Geol. Soc., vol. xxii., pt. xxi., and vol. xxiii., pt. vi.; also in Report British Assoc. for 1894, p. 662, and for 1896, p. 776; and in Colliery Guardian, vol. lxi., p. 414.

had been carried down into the solid rocks; and the details of a fourth boring were made known in 1896, by Mr. John Todd, the engineer in charge of the operations.¹ Since that time two additional borings have been completed (Nos. 5 and 6); and through the courtesy of Messrs. Craine Bros., we are enabled to include a full description of these in the following pages². Besides confirming the forecast as to the Lower Carboniferous rocks, these borings have likewise proved the existence of Triassic and Permian strata, hitherto scarcely suspected, within the limits of the Island. (See also Postscript to last chapter, p. 279.)

The recent borings have all been made upon the extreme northern margin of the drift-covered plain; and there lies to the southward a space ranging in breadth from $4\frac{1}{2}$ miles on the west to 7 miles on the east, with a superficial area of over 40 square miles, in which no direct evidence as to the solid geology is at present forthcoming. On the geological map as published, a conjectural representation of the geology of this tract has been attempted, from general considerations, as subsequently explained (p. 294); but this can be, at the best, only approximately correct. The uncertainty is rendered the greater since there is a possibility that Devonian and Silurian rocks as yet unknown in the Island, may crop out under the drift between the Lower Carboniferous beds of the borings and the hilly slope of the Manx Slates. This point will be further discussed in a later part of the present chapter.

Description of the Deep Borings.

The sites of the six borings already sunk are shown on the ground-plan on p. 283, (Fig. 79); all except No. 6 are also indicated on the published one-inch geological map. The numeration is that adopted by the proprietors, and follows the order in which the borings were made. It will be more convenient, however, to describe them in their geographical sequence from west to east, as we shall then pursue the upward succession of the solid rocks, which were entered at higher stratigraphical horizons by each boring consecutively in this direction. Through the kindness of Messrs. Craine Bros., and of Mr. J. Todd, the resident engineer, the writer was enabled to examine, while the work was in progress, the whole of the cores in their possession, and to select a typical series for the Survey Collection. The following descriptions of the sections are based on notes made during these examinations. The complete journals of the borings are printed in Appendix III., p. 578.

The glacial deposits passed through in the borings are more fully described in Chap. IX., p. 340 and XI., p. 418.

No. 3.—The Lhen Mooar Boring.

SUMMARY OF SECTION. (See also Appendix III., p. 580.)

	<i>Ft.</i>	<i>in</i>
Sand and Gravel, probably Raised Beach - - -	12	0
Glacial drift; sand, gravel and silt - - -	155	6
Carboniferous Limestone - - -	66	10
Total depth - -	234	4

¹ Yn Lioar Manninagh, vol. iii., pt. ii., pp. 65-72.

² Prof. Boyd Dawkins has included an account of the last two borings in his recent papers. (See postscript on p. 279.)

Further description.—This, the most southerly as well as the most westerly of the borings, had its site on the Raised Beach only 10 or 15 feet above high-tide level, and 50 yards from high water-mark, on the north-western coast of the Island, 470 yards N.N.E. of the bridge at Lhen Mooar.

We have no definite information as to the character of the drifts, as the boring had been completed before our visit, and specimens of the drift-deposits had not been preserved. The apparent absence of boulder-clay is singular, though in all the borings the proportion of sand and gravel to boulder-clay is greater in the drifts of these sections than in the average cliff-sections.

The rock-floor was found at within a few feet of the same depth in this boring as in borings No. 2 and No. 4, but at a less depth than in those to the eastward of No. 4. That it represents a plane of marine denudation is clearly indicated by the regularity with which it cuts such diverse rocks as the limestone of the present boring and the Triassic Sandstone of borings Nos. 2 and 4.

The Carboniferous Limestone, as shown by the cores, was throughout much crumpled and disturbed, dipping at an angle of 40° or more. It contained many calcite veins and cavities, and varied in colour from dark blue to palish grey. It abounded in fragments of encrinites, which were the only fossils recognised. It appeared to be more massive and less interrupted by shale partings than the Lower Limestone of the south of the Island, and less fossiliferous than the Poolvash Limestone.

No. 2.—The Ballawhane Boring.

SUMMARY OF SECTION. (See also Appendix III., p. 579).

	Ft. in
Raised Beach; sand and gravel - - - -	16 0
Glacial Drift; sand, clay and silt (see p. 421). - -	155 0
St. Bees Sandstone (Triassic) - - - -	371 0
passing downwards into	
Lower Red Marls (Permian) - - - -	33 4
Lower Carboniferous Series, consisting of—	
	Ft. in.
Stained limestone with encrinites,	
much shattered at the top - - - -	3 6
Hard mottled blue grit - - - -	0 9
Limestone - - - -	2 0
Purple sandstone and shale, more or less	
calcareous, with bands of stained encrin-	
ital limestone - - - -	98 10
passing down into	
Thicker beds of pale encrinital limestone,	
with gritty and shaly partings in the	
upper part - - - -	37 11
	143 0
Total depth - - -	718 4

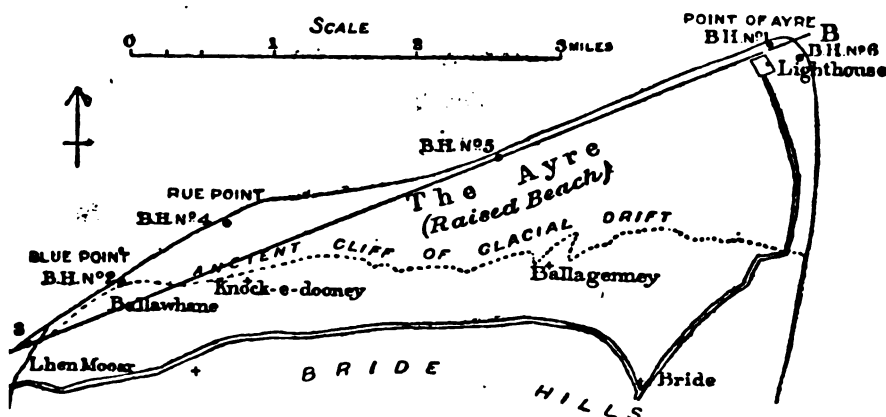
Further Description.—This bore-hole is on the narrow strip of Raised Beach on the western side of Blue Point, 70 yards from high-water mark and 1,300 yards to the north-eastward of No. 3, and at the same elevation above the sea as that boring.

The drift had been penetrated before my first visit and the material had not been kept (see p. 421). The St. Bees Sandstone resembles in all respects that of Cumberland, being a rather fine grained somewhat micaceous unfossiliferous sandstone, of brightish red colour mottled and streaked in places with greenish grey, interlaminated with thin partings of marl. These marly intercalations increase in thickness towards the base of the sandstone, thus giving a gradual passage into the Lower Marls, which again resemble those of the coast near Whitehaven except in the comparative rarity of gypsum, of which only a few thin streaks were encountered. These rocks possessed throughout a gentle dip of from 5 to 10 degrees, and showed no signs of disturbance except within a short distance of the base of the marls, where there was much slickensides, especially just above the sudden junction with the highly disturbed Carboniferous rocks.

The condition of the cores immediately at the base of the marl and at the top of the Carboniferous rocks indicated that the junction was almost certainly a line of fault. The effect of this fault is apparently to let down the Triassic and Permian rocks on the east against the Lower Carboniferous rocks on the west, thus causing the wide difference between the rocks of this boring and of the last. The fault appears to have been struck at such a level in the boring as to cut out the lowermost portion of the Permian

FIG. 79. *Ground-plan of the northern extremity of the Isle of Man, indicating position of borings and line of section (A—B) shown in Plate V.*

B.H. = Borehole.



strata from the section, so that the Brockram so well represented in borings farther eastward is not found here. The magnitude of the fault is probably considerable, judging from the thickness of the Triassic Rocks at this place on the one hand, and from the absence of staining in the Carboniferous Limestone of No. 3. Boring on the other hand, the latter fact indicating an uplift of the Carboniferous rocks to the westward sufficiently great to have carried the stained strata which must originally have underlain the Red Rocks (see p. 286) above the present plane of the denuded rock-surface. The direction of the fault can only be conjectured; on general considerations, it may be supposed to strike from some point between north and west to some point between south and east (see p. 294); and as no fault of magnitude has been detected in the Manx Slates anywhere to the southward a south-easterly course has been adopted for it on the map.

We have previously referred to the account of this boring published by Prof. Dawkins, in which the Red Marls for 33 ft. 4 in. above the fault and the Carboniferous rocks for 101 ft. 11 in. below it are combined under the heading of "*Permian Rocks of the Stack Series.*"¹ As already stated,

¹ Trans. Manchester Geol. Soc., vol. xxiii, pt. vi.

Professor Dawkins has now abandoned this reading, and grants that Lower Carboniferous rocks set in immediately below the Red Marls at a depth of 575 feet below the surface and are continuous thence to the bottom, and that no rocks comparable to the Peel Series occur in the boring. The supposed conglomerates and breccias mentioned in his account are bands of Carboniferous limestone disturbed by Pre-Permian earth-movement and afterwards partly brecciated in the vicinity of the fault: they are stained by the Red Rocks, partly dolomitised, and frequently veined with hæmatite. The Lower Carboniferous beds of which these bands form part include purple-stained sandstone and shale, alternating with limestone-bands generally full of encrinite-stems. The uppermost calcareous band occurs immediately below the Red Marls, with others at intervals throughout the next 100 feet of the section, finally giving place to the more massive limestone at the bottom of the boring; this series appears to be conformable throughout; its dips range from 40° in the upper portion to 60° in the lower part of the section, thus contrasting strongly with the gentle dips of the overlying Red Sandstone and Marls. A "conglomerate with pebble bed" 3 feet 9 inches thick is mentioned in the journal of the boring at a depth of 631 feet 2 inches; but I carefully examined the cores without finding any true conglomerate in the Carboniferous series, and suppose the entry to refer to one of the crushed limestone bands. The beds were full of slickensides for 20 to 30 feet below the junction with the Red Marl, and there were again similar symptoms of disturbance at 678 feet; but in the intervening space the crumpling and pressure-structures were of older date than the Post-Trissaic fault, and were such as usually accompany the folding of rocks. The purple sandstones and shales accompanying the Carboniferous Limestone become still more abundant eastward in the next two borings, presumably indicating that we reach higher horizons in the Lower Carboniferous series in this direction.

No. 4.—Knock-a-Dooney Boring.

SUMMARY OF SECTION. (See also Appendix III., p. 581).

	<i>Ft.</i>	<i>in.</i>
Raised Beach; sand with stones - - - - -	16	0
Glacial Drift; sand, gravel, silt, clay, etc. (<i>see</i> p. 419) -	157	0
St. Bees Sandstone (Triassic) - - - - -	335	8
passing down into		
Lower Red Marls with intercalations of sandstone		
(Permian) - - - - -	98	4
passing down into		
Brown coarse-grained sandstone with partings of marls,		
and fine "Brockram" (conglomerate) at base (Permian)	55	1
Carboniferous Rocks:—		
	<i>Ft.</i>	<i>in.</i>
Stained reddish and purplish-grey sandstone		
with deeply stained shaly layers - - -	62	2
Sandy shale with clay-ironstone nodules,		
stained dull red, passing down into dull		
purple and gradually into dark-grey and		
black shale with pyrites; slightly calca-		
reous; containing a few crushed fossils		
(encrinites; <i>Spirifera</i> , <i>Productus</i> , etc., of		
small size) - - - - -	220	2
Bands of limestone and shale - - -	17	6
	299	10
Total depth - - -		
	961	11

Further Description.—This bore-hole is distant 1,500 yards N. 58 E. from No. 2, on the Raised Beach, 30 yards from high-water mark, on the western side of Rue Point, N. 20 W. of the farmstead of Knock-e-Dooney. It is noteworthy that at all the borings, in spite of the proximity of the sea and the very porous character of the superficial material to some depth below sea-level, a supply of fresh water was obtained by excavating the Raised-beach shingle to a depth below the level of high-tide. The fresh water in these excavations rose and fell with the tide, and only occasionally became lightly brackish.

I was able to make a careful examination of the material obtained from the drift deposits of this section, and have incorporated the results in a succeeding chapter (p. 420). These drifts extended downward to about the same depth as in the preceding bores; and the top of the St. Bees sandstone immediately beneath them was soft and rubbly, being probably broken up by glacial agencies. The sandstone was identical in character with the corresponding rock of No. 2 Bore, and possessed the same low dip. In places it showed extremely well-marked cross-bedding. The early intercalations gradually increased toward the base, until they predominated over the sandstone, and constituted the Lower Marls. The lower portion of these marls was streaked with thin irregular dabs and patches of coarse sandstone or grit, and this material increased in quantity downwards until it replaced the marls which thus formed a link between the overlying St. Bees Sandstone and an underlying sandstone of a different type.

It is now usual to consider the St. Bees Sandstone as the lowest division of the Trias in Cumberland, and to class the underlying strata as Permian. It seems necessary, therefore, that we should regard the Lower Marls and the underlying beds down to the base of the Red Rocks in these Manx sections as Permian; but this classification is purely artificial, since the so-called Permian strata are simply the basement beds of the overlying marls, as indeed they are also on the Cumberland coast. These "Permian" rocks appear to have been faulted out in the boring last described, so that I have here for the first time an opportunity to examine them. Prof. Wyld Dawkins classes their upper portion with the Triassic, but ascribes their lowest part, for a thickness of 28 feet 3 inches, to "Permian rocks of the Stack Series"¹; they bear no resemblance, however, either to the Peel Rocks or to the so-called "Stack Series" of the Ballawhane boring.

The peculiar coarse brown sandstone, into which the marls passed downward as above described, is characterised by the size and also by the hardness and polish of its quartz-grains, which are set in a more or less silty matrix and in some bands exceed $\frac{1}{2}$ inch in diameter.

Toward the base it becomes streaked with a fine calcareous conglomerate breccia, of which the more or less subangular fragments, up to $\frac{1}{2}$ inch in diameter, seem to have been derived from the underlying Carboniferous rocks, being chiefly composed of dolomitised and decayed fragments of sandstone, with dull red grit, brick-red grit or sandstone, shale and quartz. In the No. 5 boring two miles farther eastward, the breccia found at the base of the Red Rocks, though of similar composition, was much coarser and thicker, and apparently replaced the round-grained sandstone. In these sections the fragments of limestone, which constitute the most abundant element of the breccia, have undergone a curious outer dolomitisation and internal decomposition by which a hollow interior lined with dolomite or calcite crystals is frequently produced. This is also a characteristic feature in the Cumberland Brockram, but is not present in the fragments of limestone in the Peel Series.

For a few feet immediately below the Brockram the cores were much shattered, and it was stated that at this point the water sank in the pipes and the boring-rods dropped as if they had broken into a small quantity. The dips, down to the base of the Brockram, had continued parallel to that of the St. Bees Sandstone, ranging between 5° and 8°; but the Carboniferous rocks were now entered and showed the usual steep inclination,—30° to 40° or over. The highest of these Carboniferous rocks

¹ Rep. Brit. Assoc., Liverpool, 1896, p. 778.

was a reddish and purplish grey sandstone, veined in places with gypsum and somewhat irregularly stained, the colour being deepest in the shaly layers. That this staining was derived from the overlying Red Rocks was strikingly demonstrated by the manner in which the red coloration faded out downwards among the underlying shales, passing gradually through shades of dull red and brownish purple into the original dark grey and black. The staining had affected the laminae unequally, thus giving rise in places to strongly marked colour-banding. The shales were full of slickensides and puckering, and showed other indications of severe compression. In their lower portion they contained many small round pyritous concretions, sometimes marked with slickensides on the surface. Considering the abundance of fossils in the Lower Carboniferous rocks of the south of the Island, the dearth of organic remains in these shales was somewhat remarkable. Towards the base they contained a few badly preserved and scarcely identifiable shells of small size, referable to the genera *Productus* and *Spirifera*, together with scattered encrinite stems also unusually small. These beds became more calcareous downward, until bands of shaly limestone were reached, while the lowest rocks pierced (of which I saw only a few specimens and not the whole of the cores) included some thicker beds of greyish crystalline limestone. It is probable that these beds represent a higher horizon than the massive limestone of No. 3 Boring. Prof. Dawkins refers the sandstone and shales to the Yoredale Series, but it seems scarcely advisable to extend that ill-defined local term to a district so remote from the place of its origin on the scanty evidence we possess at present.

Allowing for the angle of dip, we may estimate the thickness of the Carboniferous rocks pierced in this boring at about 235 feet.

No. 5.—Ballagenney Boring.

SUMMARY OF SECTION. (See also Appendix III., p. 583.)

	<i>Ft. in.</i>
Raised Beach; sand and stones - - - - -	15 0
Glacial Drift; sand, gravel, clay, etc. (<i>see</i> p. 418) - - -	197 4
St. Bees Sandstone (and Lower Marls, inseparable), passing into	792 2
Marl with coarse sandstone and fine "Brockram," passing into	17 6
Coarse "Brockram"-conglomerate - - - - -	19 6
Carboniferous Rocks:—	<i>Ft. in.</i>
Purple sandstone and sandy shale with casts of <i>Productus</i> (?) and other shells in a band 36½ feet from top - - - - -	45 3
Purplish, reddish and grey sandstone with shaly layers; containing obscure plant remains, including <i>Lepidodendron</i> and <i>Stigmaria</i> - - - - -	87 1
Dark purple shale and impure limestone, with badly preserved marine fossils (<i>see</i> list, p. 288) - - - - -	61 3
Stained sandy limestone and calcareous sandstone, with shaly layers; much dis- turbed and partially brecciated in places; containing badly preserved marine fossils (<i>see</i> list) - - - - -	62 5
	256 0
Total depth -	1,297 6

her Description.—This boring, which up to the present time is the of the series, lies at a distance of two miles E. 14 N. from No. 4, most exactly half-way between No. 4 and No. 1 (Point of Ayre). ie others, it is at the seaward edge of the Raised Beach, here quarters of a mile broad, and is about 30 yards from high-water and a few yards to the westward of the cart-track leading from nney farm to the shore.

amination of the material obtained from the superficial deposits that, as in all the borings, in spite of the depth below sea-level, the beds extended down to the solid rock, and that no Pre-Glacial or y strata were present (see p. 420).

St. Bees Sandstone agreed in all respects with the same rock in the sections, except that it was much thicker, from this boring entered it at a higher horizon, and in a minor degree from the Marls being so much interstratified with the sandstone as to be ger separable as an independent division. The deposit probably nearly its full thickness here, as calculation from the dip will show e overlying Upper Saliferous Marls proved in the Point of Ayre should extend nearly to this place.

w the St. Bees Sandstone the succession differed from at boring, not only in the less distinct development of ower Marls but also in that the brown sandstone with d grains was represented only by thin streaks of coarse sand atified with marl. This gritty marl mingled gradually downward onglomeratic "brockram" which was at first scanty and of fine , but increased rapidly in quantity and coarseness down to the here it contained blocks of dolomitised limestone, sandstone, etc., 6 inches or more in diameter. The "brockram" as developed ; section very closely resembled the corresponding rock of the rland coast-section near Whitehaven.

eat unconformability was again found at the base of the Red Rocks, ow and regular dip of 5° to 10° giving place suddenly to and disturbed strata of Lower Carboniferous age dipping at 15°. These Carboniferous rocks differed widely from those in No. 4 and only in part resembled the series in No. 2. The stained me of the uppermost portion was strongly cross-bedded; it passed nto mottled green and purple shale, strongly slickensided along the g planes. A band of dark purple sandstone, 7 feet 3 inches in ss, occurring at a depth of 36½ feet from the base of the brockram, riginally have been a fossiliferous calcareous grit; but the lime was l out, leaving obscure casts of shells among which *Productus virifera* were recognised.

w the shelly seam was a band, 1½ feet thick, of very hard close-l grit—almost a quartzite—not unlike certain thin bands passed h in the No. 2 Boring. In the succeeding 87 feet of stained ones and sandy shales no marine fossils were found, but some of the ere full of obscure plant remains, among which *Lepidodendron* and *aria* have been recognised. At a depth of 1,173 feet 10 inches from face there was a rather sudden change to calcareous shales full of fossils, encrinites predominating, and these shales, with intercalations ure limestone and sandstone, continued to 1,235 feet; while below o the bottom of the boring, the rocks consisted chiefly of stained limestone or calcareous grit, with numerous fossils, among which tes were not so conspicuously abundant as at the higher level. The the fossils of the boring given on the next page has been prepared rsrs. Sharman and Newton from specimens preserved in the Survey ion. The dips in the lower part of the Carboniferous rocks were hat steeper than in the higher part, ranging between 45° and 50°. ady persistence of dips approximating to 45° in this series, extending ions 3½ miles apart, when taken in connection with the disturbed ter of the bedding, is a strong indication of the presence of systematic

folding. In the present boring especially, most of the shales and thinner limestones were much crumpled and partially brecciated, showing 'fluxion structure' of the bedding planes and in some cases a fracture like incipient cleavage; slickensides and polished surfaces were also abundant throughout.

Some thin veins of gypsum cut across the bedding-planes in the lower part of the section. The staining of the rocks in different shades of red and purple was again a marked feature, and extended, in varying degrees, to the bottom; at 1,197 feet from the surface, where a strong joint or fault accompanied by a brecciation of the shale was passed through, the staining was accentuated.

In this section, as in No. 2 and No. 4, we find that the limestones are subordinate to beds composed of sandy and shaly material. These facts suggest that the Lower Carboniferous rocks of the north of the Island are likely to correspond more nearly to the strata of similar age in the south-west of Scotland than to those of any part of England, as indeed might be expected from their geographical position. The presence of sandstone with plant remains, intercalated with beds containing marine fossils, affords further evidence in this direction.

There were, again, no rocks in the boring that could be correlated with the Peel Sandstone notwithstanding that the base of the New Red series was again revealed; and, as stated in the previous chapter, this evidence tells strongly against the supposed Permian age of the Peel series.

LIST OF FOSSILS FROM THE CARBONIFEROUS ROCKS IN THE
BALLAGENNEY (No. 5) BORING.

At depth of 1,078 feet from surface:

*Casts of *Productus* ? and *Spirifera* ?

At about 1,165 feet:

*Impressions of vegetable remains, including *Stigmaria* and *Lepidodendron* ?

At 1,176 feet:

Spirifera trigonalis ? and fragments of other shells.

At 1,182 to 1,189 feet:

(Sponge) *Hyalostelia* sp.
(Crinoid) Encrinite stems.
(Polyzoa) *Fenestella* sp.
Rhombopora megastoma ? McCoy
(Brachiopoda) *Chonetes laqueosiana*, de Kon.
Productus scabriculus, Mart.
" *longispinus*, Sow.

At 1,200 feet:

(Annelid) *Spirorbis* sp.

At 1,208 to 1,210 feet:

Encrinite stems.
Fenestella sp.
Chonetes laqueosiana ? de Kon.
Fish tooth.

At 1,282 to 1,290 feet:

Encrinite stems.
Productus longispinus, Sow.
" *punctatus*, Mart.
" *semireticulatus*, Mart.

*The fossils marked thus were only seen by the writer in the cores at the boring; the remainder were determined by Messrs. Sharman and Newton.

No. 1.—Point of Ayre First Boring.

SUMMARY OF SECTION.—(See also Appendix III., p. 578.)

Raised Beach; shingle	- - - - -	23 feet.
Glacial Drift; sand, gravel, silt, and clay	- - - - -	275 "
Triassic Red Marls, with gypsum and rock-salt	- - - - -	332 "
Total depth	- - - - -	<u>680</u> "

Further Description.—This boring, commenced in 1891, was the first of the series. Its position, 2 miles distant E. 25 N. from No. 5, is on the Raised Beach, close to high-water mark, at the extreme northerly point of the Island.

It had been completed before I visited the place, and the drift material had not been preserved. Through the kindness of Mr. J. Todd, however, we have been supplied with a full set of specimens from the corresponding drifts of the later boring, No. 6, which lies only 335 yards south-eastward from No. 1, and have been thus enabled to make a careful study of the exceptionally interesting glacial section at this place (see p. 340).

In the No. 6 boring the Glacial deposits appear to extend to the remarkable depth of at least 428 feet below the surface, the middle portion consisting mainly of sand and gravel, in places full of marine shells, and the lowest part, of re-arranged red marl with foreign stones. From the difficulty in distinguishing between the latter material and the Triassic marl in its original state, it is possible that the drift in the present boring was thicker than stated; the diamond drill was not used until a depth of 52 feet was reached, and the difference between drift and solid of similar composition would be scarcely perceptible in the fragments broken up by the chisel. Otherwise the difference of over 100 feet between the thickness of the drift in these contiguous sections would denote a most uneven surface of the solid rocks in this quarter; and this, though not inherently improbable, is opposed to the evidence of the former borings, which indicated a regular plane of erosion beneath the drifts (see Pl. V.) Nowhere in the British Islands, so far as I am aware, have the Glacial deposits been proved to so great a depth as in these two borings (see p. 344).

The Triassic marls were red and brown in colour, mottled and streaked with greenish grey. They were thinly veined throughout with gypsum, and contained crystals and pseudomorphs of rock-salt. In the lower part of the section several bands of rock-salt were passed through, having an aggregate thickness of 33½ feet, the thickest bed (20 feet) occurring at 635 feet 2 inches from the surface. A brine-run 2½ feet in depth was also intercepted, and preparations are now in progress for turning the discovery to economic account (see Appendix, p. 579, also Chap. III., p. 559).

Prof. Dawkins has pointed out the great theoretical importance of this discovery, which "links on the salt-field at Carrickfergus with those of Barrow and of Cheshire, and shows that the Irish Sea is a basin in which the salt-bearing Triassic marls were deposited. They have since been broken up and denuded, and it remains to be proved how far they are continuous under the sea, eastward to Barrow and to the north-west in the direction of Carrickfergus."¹

¹ Rep. British Assoc., Liverpool, 1896, p. 778; also Trans. Manch. Geol. Soc., vol. xxii., pt. xxi.

No. 6.—Point of Ayre Second Boring.

SUMMARY OF SECTION.—(See also Appendix III., p. 585.) *Ft. in.*

Raised Beach; shingle	-	-	-	-	16	0
Glacial Drift:—consisting of—					<i>Ft.</i>	
Sand and gravel with broken marine shells	-	-	-	-	97	
Stony clay with some sand	-	-	-	-	102	
Muddy sand and gravel with many shells	-	-	-	-	25	
Reddish sand and gravel apparently derived in great part from Triassic rocks; shell fragments very small and rare; a large boulder 9 feet above the base	-	-	-	-	123	
Local drift of reconstructed Triassic marl with a few erratic pebbles	-	-	-	-	65—412	0
Disturbed Triassic Red Marl: probably partly reconstructed by glacial agency (containing a few foreign pebbles at 476 feet from surface) about					65	0
Triassic Red Marl (stratified), with gypsum and rock-salt					382	8
Triassic Red Marl with sandy bands	-	-	-	-	44	8
Total depth					920	4

Further Description.—This boring is near the edge of the Raised Beach 262 yards east of the Point of Ayre Lighthouse, and, as already stated, only 335 yards south-east of No. 1 Boring. It was sunk in 1897-8 for the purpose of testing the extent of the Saliferous Marls. Our field-work in the Island had been completed before it was commenced, but through the kindness of Mr. J. Todd and Messrs. Craine Bros., we have been supplied with specimens of the cores at short intervals throughout the section; and the following notes, as well as the fuller details of the Glacial deposits given in the subsequent chapter (p. 340) have been based on our investigation of this material.

From the base of the Raised Beach at about 16 feet from the surface down to 363 feet the drift was composed chiefly of stratified material, in the main resembling that of the other borings, but about midway containing a marine shell-bed different from any deposit known to exist elsewhere in the Manx drifts (see p. 342). Below the stratified drift we seemed to have a thick mass of local till consisting of reconstructed gypseous Red Marl sporadically mixed with a few pebbles of extraneous origin. These drift pebbles were present in all the samples examined by us down to 428 feet (see p. 343), but were absent from the lower material at 453 feet and at 462 feet, which consisted entirely of broken-up marl and gypsum, until the depth of 476 feet was reached, where in the specimen supplied to us, the foreign pebbles reappeared. If the depth was correctly marked on our specimen, this may indicate that large masses of the upper portion of the marl have here and there been displaced *en bloc* by glacial action, after the manner well known in the east of England. In the journal of the boring, however, the drift seems to have been recognised below 363 feet, and the classification in the summary given above rests on the evidence of our specimens (see p. 586).

Although no extraneous material was observed in the samples below 476 feet, the marl continued to present a reconstructed aspect, without original bedding, down to a depth of about 535 feet, where its stratification first became apparent. The dips were irregular and the material disturbed for some distance further; and, in fact, the cores throughout appear to show much irregularity in this respect, which may perhaps be explained by local subsidences of the marls into hollows left by the removal of the salt in solution.

The chief saliferous beds lay between the depths of 604 and 875 feet, the mineral occurring in numerous bands, either pure or mixed with varying proportions of marl (for full details see Appendix III., p. 586). The following statistics of the salt deposits of this boring have been placed

MAN, ALONG THE LINE A-B OF THE GROUND PLAN OF THE AYR

AL SCALE.

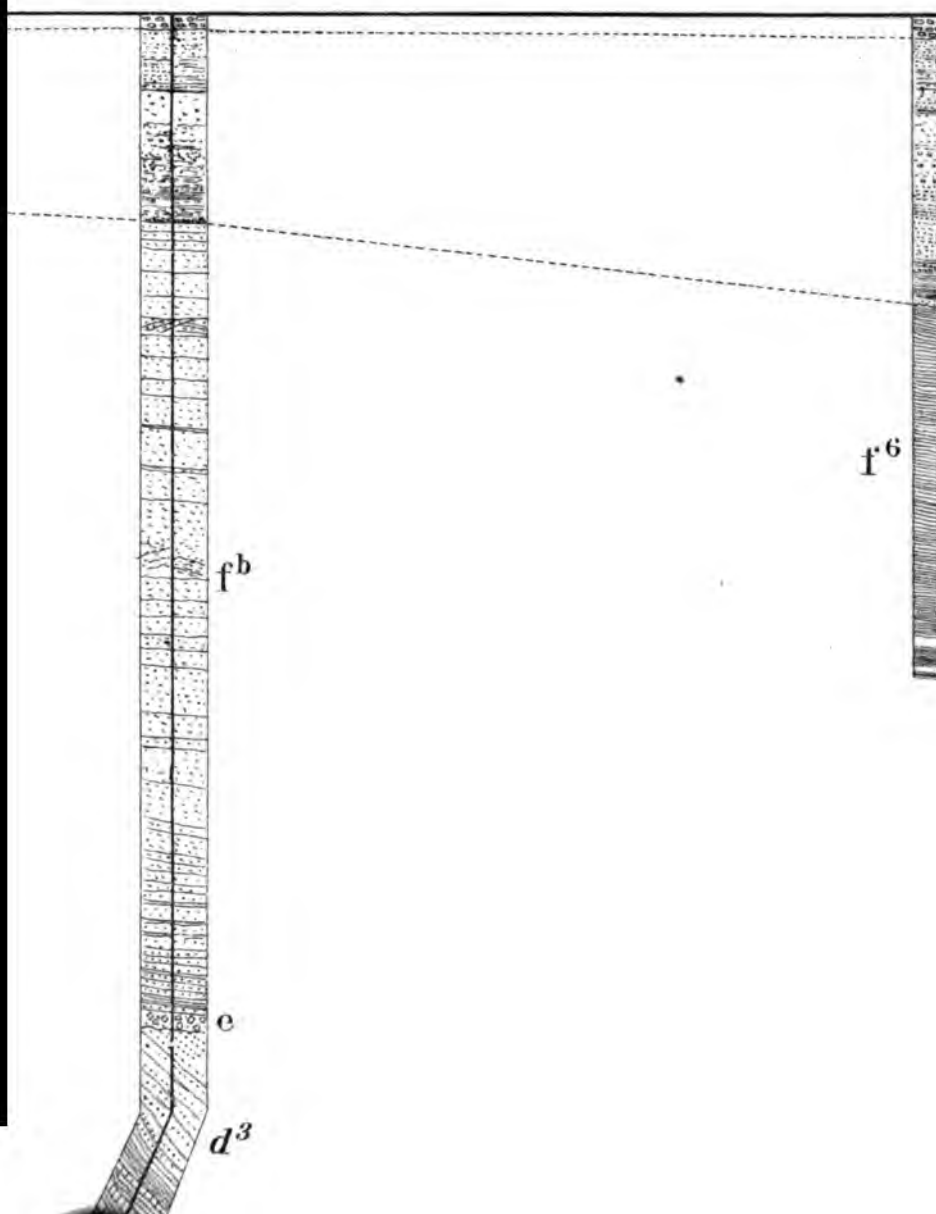
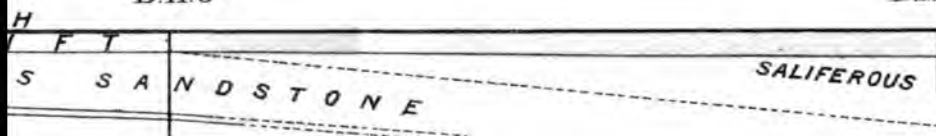
2 MILES

Ballagenney

B.H.5

Point of Ay

B.H.



disposal by Mr. Todd :—Salt (cores obtained) 76 ft. 8 in.; Salt with 20 per cent. of Marl 10 ft. 4 in.; Salt with about 25 per cent. of Marl Salt with about 50 per cent. of Marl 8 ft. 3 in.; Marl with about 30 per cent. of Salt 11 ft. 6 in.; Marl with about 10 per cent. of Salt 2 ft. 10 in. Now 875 feet, to the bottom of the boring, the marls were interstratified in thin bands of marly sandstone of the usual character of such interbeds in Keuper Marls.

General Deductions from the foregoing Evidence.

The fine series of borings above described enable us to construct a section completely across the extreme north of the Island, from E.N.E. to W.S.W., as shown in Plate V. We will now proceed to discuss this section and the probable 'solid' stratigraphy of the New Red ground to the southward.

New Red Rocks.

The Triassic and Permian strata of our section correspond exactly to the rocks of similar age on the opposite Cumberland North Lancashire coast, the chief difference being that the Mesian Limestone, which is reduced to a thickness of about 10 feet at Whitehaven, is altogether wanting in the Isle of Man. The Manx Red Rocks are even more strongly unconformable on the underlying Carboniferous than on the mainland; and it is probable that they have once extended across the denuded surface of the Carboniferous strata up to and over the flanks of the Manx Slates of the central massif exposed by Pre-Permian erosion, exactly as they overlap upon the Skiddaw Slates on the western margin of the Lake District. Some traces of this overlap seem still to be preserved, in the occurrence of bodies of hematite and the prevalence of red staining in the lodes and veins in the slates in the north-eastern corner of the massif.

The gentle dip and undisturbed condition of the New Red Rocks throughout the borings, in strong variance with the steep and disturbed state of the underlying Carboniferous strata, show that, as compared with the Pre-Permian disturbances, the movements in this district since Triassic times have been very simple. As on all the opposite shores of the Irish Sea, the later movements of elevation and depression seem to have been effected by normal faulting only. That the northern part of this sea-basin was already troughed out in Permian times is indicated by the manner in which the New Red Rocks are distributed in depressions adjacent to its shores, in the north-west of Ireland and the south-west of Scotland, as well as in the north-west of England.

The direction of dip of the Red Rocks was not actually ascertained in the borings, but the incoming of the higher members of the series towards the north-east is sufficient to show that their general dip must be approximately in that direction. The line of section shown in Plate V. is therefore somewhat oblique to the dip.

There is a strong probability that the neighbouring part of the Irish Sea is mainly underlain by the rocks of this age will deserve special consideration in case the proposed scheme for a submarine

tunnel between Scotland and Ireland should ever reach the practical stage.

Lower Carboniferous Series.

The disturbed condition of the Carboniferous strata in the borings precludes any positive conclusion as to their sequence or direction of strike. They appear to have been more severely affected than the rocks of this age in the south of the Island. Judging from the analogy afforded by the Carboniferous rocks of other districts, it seems likely that their general strike will run more or less paralld to the nearest margin of the old slate-massif, and therefore approximately east and west, with a general northerly dip. This agrees with the conclusion reached on other grounds, that the newer members of the series occupy the more northerly positions, and that the line of the borings diverges north-eastward at a low angle from the strike of the strata. The fossil evidence is unfortunately too scanty to afford much assistance, as the species recorded are all common Lower Carboniferous forms. The absence of the corals found in the calcareous bands of the Peel Series is, however, noteworthy.

It seems probable, then, that the massive limestone of No. 3 Bore is the lowest stratigraphical horizon which has been reached. From the geological standpoint it is to be regretted that this boring was not carried deeper, though of course nothing of economic value was likely to be thereby attained. As the case stands, with allowance for the dip we find that about 45 feet of limestone was penetrated, which is the thickest mass of calcareous rock passed through in the borings.

In the next section north-eastward (No. 2 Bore), the Carboniferous rocks contained at first only thin bands of limestone, subordinate to calcareous sandstone and shale, but thicker limestones were reached at the bottom of the boring.

In the succeeding boring (No. 4) the first 282 ft.¹ of Lower Carboniferous rocks consisted of 62 ft. of sandstone, underlain by 220 ft. of dark sandy shale; and bands of limestone made their appearance only below that depth.

Finally in the boring (No. 5) farthest to the north and east which has hitherto reached the Carboniferous, it consisted for about 140 feet of sandstone and sandy shale only, containing plant-remains as well as marine shells, and below there were impure limestone bands among the shales.

Thus the last three sections all showed, though in varying degree, the same tendency towards a downward passage into limestone, the borings being suspended when the thicker bands of limestone were reached. This leads to the conclusion that the sequence consists of a series of sandstones and shales, with thin limestone bands in their lower part, overlying more massively-bedded limestone of unknown thickness.

It is noteworthy that no trace whatever was found of the Carboniferous Volcanic Series of the south of the Island.

¹ As measured in the borehole; not corrected for dip.

As regards the hypothetical downward continuation of the section below the Carboniferous limestone touched in No. 3 Bore, I think the most probable inference is that rocks equivalent in age and similar in character to the Peel Sandstone will occupy this position. Indeed the absence from all the borings of any rocks comparable to the Peel Series seems necessarily to imply that if the series is represented at all in the north of the Island, it must lie below the Carboniferous Limestone found in the borings. If Cumming's suggestion be correct, that the Peel Rocks represent simply a belt of shore-deposits of the early Carboniferous sea, like the conglomerates of Langness, it is possible that they may have passed laterally into Carboniferous Limestone (as similar beds are known to do at the western margin of the Carboniferous basin in Ireland) at a short distance from the flanks of the slate massif,¹ and may therefore have become attenuated and largely replaced by limestone before reaching the northern limits of the island. But in view of their considerable thickness north of Peel and the far-drifted and non-local aspect of many of their pebbles, it seems more probable that the sandstones have originally extended over a wide tract of sea-bottom, and therefore are likely to underlie the Carboniferous Limestone of the northern plain, and if fully developed, to represent, as in some parts of Scotland, the transition from Upper Devonian to Carboniferous times. The resemblance between the Peel Series and the Calciferous Sandstones which form the lower portion of the Carboniferous system in Kirkcudbrightshire, commented on in the preceding chapter (p. 265), suggests a common basin of deposition, that would probably include the north of the Island, which is over 12 miles nearer that coast than is the Peel outcrop. If, therefore, the beds underlying the Carboniferous Limestone had been penetrated in the borings, it is probable that they would have been found more to resemble the rocks of the same age in Scotland than those in Cumberland.

The most probable downward sequence of the concealed Lower Carboniferous strata of the north of the Island will therefore read as follows:—

3. Sandstones and shales, with thin limestone bands in the lower part.

2. Limestones.

1 Sandstones and Conglomerates of the Peel Series.

The already proved extent and diversity of these rocks indicate that their aggregate thickness must be great, certainly far exceeding that of the Carboniferous strata of the south of the Island; it may reach some thousands of feet.

Probable Stratigraphy of the Low Ground South of the Borings.

As mentioned at the commencement of the present chapter, between the borings and the nearest outcrop of the Manx Slates there is a space from $4\frac{1}{2}$ to 7 miles wide, stretching right across

¹ For general discussion of the facts relating to Ireland see G. H. Kinahan's "Geology of Ireland," p. 64 *et seq.* (London, 8vo., 1878.)

the Island, in which evidence as to the solid geology is lacking but for which it was imperative to prepare a conjectural reading, in order to complete the 'solid' edition of the geological map in accordance with the conventional system adopted by the Geological Survey of showing the 'solid' colouring in all tracts not covered with alluvium. This area, of over 40 square miles, is, to all intents and purposes, geologically a portion of the bottom of the Irish Sea, which has been converted into dry land by the locally profuse deposition of Glacial drift. The 'solid' lines adopted for this tract are necessarily and essentially hypothetical; hence a brief statement of the considerations which have weighed with me in drawing them may be found useful.

Starting in the extreme north, at the Point of Ayre, we have to deal first with the Triassic Saliferous Marls revealed in Bores Nos. 1 and 6. We know that these rocks do not extend westward to Bore No. 5; and concluding, for reasons already stated, that their dip is probably towards the north-east, we find, by calculation from their proved thickness that their line of outcrop is likely to be just covered by the tract of Raised Beach and Blown Sand forming the eastern part of The Ayre; and as these superficial deposits, being akin to Alluvium, are shown on the 'solid' map, we gladly evade the necessity for separately colouring or drawing a boundary-line for the Marls.

The St. Bees Sandstone which directly underlies the drift in Bores Nos. 5, 4, and 2, is likely, from its thickness and gentle dip, to extend for some distance inland in the eastern portion of the tract, outcropping from beneath the Saliferous Marls near the southern margin of the Raised Beach, while westward it is probably faulted off against the Carboniferous Limestone of Bore No. 3, as already described. The proved existence of this Post-Triassic fault, taken in conjunction with the known prevalence of faults in the Carboniferous rocks in other parts of the Island, and on the opposite Cumberland coast (where the Whitehaven coalfield is cut into strips by dislocations of two distinct ages, some being Pre-Permian and others Post-Triassic), leaves no doubt that many other faults must exist in the area we are considering, and must profoundly modify its stratigraphy. But we are compelled to ignore this factor except in the one case proven, and to calculate the inland extension of the St. Bees Sandstone from its known thickness and probable north-easterly dip.

The Permian Brockram and associated beds proved in Bores Nos. 4 and 5, are shown as a narrow belt outcropping along the southerly margin of the St. Bees Sandstone, the breadth being somewhat exaggerated on the one-inch map for the sake of clearness. On the evidence of Bore No. 2, it is indicated that these rocks are cut off westward by the above-discussed fault.

There is, however, some probability that the Permian and Triassic strata may stretch farther southward on the eastern side of the Island than we have ventured to extend them; they may, indeed, in this quarter entirely overlap the Carboniferous Limestone.

The Carboniferous Limestone Series, which was found to be covered by the New Red Rocks in all the borings except No. 3, is shown outcropping to the southward, in a broad belt on the west, narrowed eastward by the above-mentioned fault and by the unconformable overlap of the Permian and Trias. The southern boundary has been bravely drawn parallel to the northern termination of the slate massif, but can be justified only by the necessity of placing it somewhere between the Red Rocks and the mountains.

It is clear that the massif has been truncated at some period prior to the Glacial epoch by marine action. Hence we must presume that there exists at the foot of the old cliffs a platform of erosion in the Manx Slates, stretching northward and marking the extent to which the cliffs have been cut back. The greater part of this platform will lie beneath the alluvium of the Curragh, and in this tract we escape the responsibility for delineating it; but on both flanks of the Island the drift is heaped up on it above alluvium-level, and there it has been represented. Its breadth is a matter of pure surmise, and is likely to be less than we have allowed.

We have now to fill in the space, still far too wide, between the edge of this platform and the southern boundary of the Carboniferous Limestone Series; and the only rocks available for this purpose seem to be the hypothetical equivalents of the Peel Series. There is, indeed, a distinct probability that strips of Silurian and Devonian may lie hidden in this quarter, but it is out of the question to introduce rock-systems into the map without some kind of evidence for their existence. If a boring were sunk to the solid rocks in the middle of the plain in the neighbourhood of Andreas it could not fail to throw light upon these problems, but unfortunately there is no likelihood that it would yield results of economic value, and therefore little chance that it will ever be undertaken.

Hence, however disinclined we may feel to allow such broad outcrops to the Lower Carboniferous rocks and to their suppositious basement beds, especially when we bear in mind the high dips of the former in all the borings and of the latter at Peel, there seems at present to be no better alternative than that which has been adopted, given the necessity for producing a map of the area on the existing evidence.

CHAPTER VIII. THE IGNEOUS ROCKS.

Introduction.

The particulars as to the localities and mode of occurrence of the igneous masses and dykes of the Island have been given along with the topographical details of the sedimentary rocks into which they are intrusive (Chapters IV. and V.), so that it remains only to discuss their classification, general relationship and petrographical characters in the present chapter. The petrographical study of the rocks has been carried out by my former colleague, Professor W. W. Watts, as explained on p. 95; and, unless otherwise stated, the descriptions of microscopic slides and general petrographical notes given in the following pages are from his pen.

The dyke-rocks of the Island are especially numerous and varied, and their study is in many instances rendered peculiarly difficult by reason of the great mechanical deformation and mineral alteration which they have undergone. Several distinct periods of intrusion are represented; but owing to the limited range of the sedimentary rocks, the age of the different intrusions can be only approximately determined, though their relative order can sometimes be fixed within certain limits. The time-classification adopted for the igneous rocks is therefore as follows:

- | | | |
|--------------------------------|-----|---|
| <i>I. Pre-Carboniferous</i> | { | including by far the greater part of the basic, intermediate and acid dykes and bosses intrusive into the Manx slates; and also the granites. |
| <i>II. Carboniferous</i> | - { | chiefly confined to the basic intrusions in the vicinity of the Carboniferous volcanic outburst at Scarlet, but doubtfully represented by a few basic dykes in the Manx slates of other parts |
| <i>III. Post-Carboniferous</i> | { | comprising only the olivine-dolerite group of dykes, supposed to be of Tertiary age. |

I. Pre-Carboniferous Intrusions.

The proof that the small basic and intermediate dykes by which the Manx slates are riddled are in most cases of Pre-Carboniferous age is directly afforded by the sections at Langness (described in Chap. V.), where the basal conglomerate of the Carboniferous is seen to rest upon the denuded edges of these dykes, as shown in Fig. 50, p. 191. The granites and their associated elvans are proved by the field-evidence to be newer

than most of these 'greenstones.' The evidence that they also are Pre-Carboniferous is less direct, resting mainly, so far as the Island alone is concerned, in the sheared condition of many of the elvans from the effect of earth-movements which were probably Pre-Carboniferous (see p. 72 *et seq.*). On like evidence, and because of their absence from the Carboniferous tracts in spite of their presence in adjacent slates, the mica-traps and some other dyke-rocks are believed to be also Pre-Carboniferous.

Before further discussing their grouping and petrographical characters it will be advisable to give a brief recapitulation of the general condition of the rocks in the field. The basic and most of the dykes classed as intermediate may for this purpose be combined into a group to which the old term 'greenstone' is roughly applicable—and indeed, in many cases when the rock is much altered, no closer definition of its affinities is attainable. These 'greenstones' however may include rocks of different ages; and they vary much in their present condition, though probably all are Pre-Carboniferous; on the published map they have been sub-divided according to state of preservation into two sets, lettered respectively Bⁿ ('Greenstones') and B^g ('Altered Greenstones').

The majority of the 'greenstone' dykes are small in size, ranging from a few inches to 3 or 4 feet across; a few, however, are larger, attaining a width of 10 or 20 feet, but rarely more. They usually strike in the same direction as the slates, though sometimes locally diverging from this direction on the crests of folds and in traversing the harder portions of the Slate series.

From this parallelism of strike the dykes often resemble and have sometimes been mistaken for sills; but almost invariably a deep section at right angles to the strike will show that the bedding of the sedimentary rock is cut wherever it swerves from the 'dominant direction of dip' (p. 73), as in the crests and troughs of folds. This 'dominant dip,' as previously explained, is essentially a 'shear-cleavage' (p. 81). Like the dykes, it maintains its direction in places where the true bedding of the slates is locally aberrant. It is instructive to find that the parallelism of the dykes with the shear-cleavage is usually maintained where both cross the true bedding.

The sedimentary rocks must have been folded, packed, and in places reduced to the condition of 'crush-conglomerate' before the injection of these dykes (p. 68 and Figs. 7, 14); but it is none the less certain that the area has undergone further movement since their injection, as the dykes have been severely torn and crushed. In a few instances they even seem to have been sharply folded; as, for example, in the cliff between Tableland Point and Port-e-Myllin, near Ramsey, and again on the west coast in Niarbyl Bay; but in such cases it is difficult to decide whether the structure is true folding, or is due to the molten rock having followed an already folded bedding-plane.

Owing to the distortion they have undergone, it is rare to find the older dykes continuous for many yards, either horizon-

tally or vertically. They have generally been dragged out into a series of curved and disconnected lenticles, as shown in the diagram Fig. 31 (p. 88), and the section Fig. 43 (p. 175). There are many indications that the later movements have been intensified along the dyke-filled fractures, and have there produced their greatest effect. Probably the dyke-rock was less amenable to stretching than the country rock, and was consequently dragged into segments.

The remarkable changes in intimate structure that have taken place in the smaller dykes in consequence of these movements deserve especial notice. The 'greenstones' are frequently sheared into a platy grey schist, scarcely distinguishable from the surrounding slate-rock, so that in small exposures it is often extremely difficult to recognise them as intrusive rocks; and, as will presently be shown, their original structure has been so thoroughly obliterated in such cases that even the microscope can lend but little aid in discriminating them.

Every stage in the crushing of these dykes may be studied, from a mere slight fracturing and distortion of the original crystalline constituents to the production of a calc-chlorite schist in which all trace of igneous structure is lost. In intermediate stages it frequently happens that the intrusive character of the rock is more readily recognised in hand-specimens than in microscopic slides, owing to the extremely decomposed condition of the minerals. For the same reason it is comparatively easy to separate in the field certain highly-sheared fine-grained greenstone-schists, usually of pale grey or greenish-blue tints—probably representing the oldest 'greenstone' intrusions of the Island—from other dykes which are less sheared, darker and greener in colour, coarser in texture, and probably of later age, though the difference between them is scarcely observable under the microscope.

Sometimes in the broader dykes the margin is crushed down to a schist, while the interior is comparatively uncrushed and exhibits the original igneous structure, even though its original minerals are much decomposed. The *Horse Rock*, under the Kioney Ghoggan cliffs, described on pp. 175-6, affords a good example of this condition.

The micro-granite dykes or elvans associated with the Foxdale Granite and with the Dhoon Granite, as previously stated, are distinctly newer than the greenstones (pp. 128, 168, and Figs. 35, 36), and, on the whole, are much less crushed. They have nevertheless undergone considerable deformation, especially along their margins or where exceptionally thin, and have been broken into segments like the greenstones (see p. 171, and Fig. 4), and occasionally reduced to a platy schist.

A few general notes on the local distribution of the Pre-Carboniferous dykes may be useful here. The 'greenstones' are found in every part of the Manx Slate area, but are unequally distributed. It is in the coast-sections that they are most readily recognised; in the interior, as a rule, they weather more

rapidly than the country rock, and consequently their presence is often concealed, or is indicated only by the occurrence of fragments of rotten ferruginous schist. They are most abundant in the tracts of striped slates and slaty flags, especially in such rocks in the south and south-east of the Island, and are rarest among the harder greywackes and grits; in one place, however,—around St. Ann's (Santon) Head—they are rather numerous among rocks of the last-mentioned type. The high ridges of Barrule Slate in the middle of the Island do not appear to contain many of these dykes, though they are abundant in the flaggy slates on both flanks. Few were found in the north-western corner of the massif, west of Sulby Glen, but this may be in part due to the weathered character of most of the rock-exposures in that district.

On the coast the dykes tend to form clusters, in which they are thickly set, with intervening tracts containing only isolated dykes. Their development appears to reach its maximum in the vicinity of the coast on both sides of the Island, if it be not that the cliff-sections foster an erroneous impression in this respect. On the east coast they are particularly abundant on Langness and the coast northward to Port Grenaugh; and in Bulgham Bay and its vicinity; and on the west coast north of the Peel Sandstone; and again, south of Port Erin. Their strike in individual outcrops throughout the Island is most commonly $W. 20^{\circ}-30^{\circ} S.$ — $E. 20^{\circ}-30^{\circ} N.$; but it is evident that, as discussed and illustrated at p. 88, Fig. 31, their true direction as a whole is more nearly $S.W.$ — $N.E.$

The bosses or segments of greenstone shown in Fig. 41, p. 162, affords a further instance of this arrangement. These appear to form part of a chain traceable north-eastward from near Dalby to an area north of the central valley. Small isolated bosses of the same kind occur here and there in other parts of the Island; they may possibly represent the main conduits of the molten matter, from which the dykes were fed.

The micro-granite dykes are much more confined in their distribution, being found only in the central belt of the massif, as described in a previous chapter (p. 114) and shown in the sketch-map, Fig. 29. The majority are clearly connected with the two principal granitic intrusions. Their general direction is nearly the same as that of the greenstone dykes; their association with the belt of altered slates has been previously discussed (p. 114).

The remaining Pre-Carboniferous dykes include a few mica-traps, felsites, and rocks of ill-defined characters. The conditions under which these occur are usually like that of the dykes already described; further information regarding them will be found in subsequent pages.

The following notes on the greenstones, with their petrographical classification, has been contributed by Professor W. W. Watts. Mr. B. Hobson included a description of a few of

these rocks in his paper "On the igneous rocks of the south of the Isle of Man,"¹ and was the first to apply the microscope to their study; they were classed by him as diabases and diorites.

PETROGRAPHIC DESCRIPTION OF THE GREENSTONES AND
MICA-TRAPS. (*Prof. W. W. Watts.*)

Diorites and Lamprophyres.

"The following slides are taken as typical of this group of dykës, and the subsequent general description is based on the characters observed in them :—

- [E. 1800.] Dyke at gullet near Hotel at Langness : Diorite (camptonite).
- [E. 1814.] Dyke at small quarry in field near wall n.w. of *The Gouyr*², Langness : Diorite (camptonite).
- [E. 1941.] Dyke in field 20 yards s. of *Claberry*, Langness : Augitic Diorite (camptonite).
- [E. 2538.] Boss, coast 200 yds. n.w. of *Bruggan Point*, Garwick : Diorite (penetrated by granophyre vein).
- [E. 2503.] Same as [E. 2538], another part of boss : Augite-Diorite (penetrated by granophyre vein).
- [E. 1964.] Dyke or boss on shore at s. side of *Niarbyl*, about 70 yds. s.w. of cottages : Altered Diorite.
- [E. 1811.] Boss, west side of *Gullet ny Gury*, Langness : Camptonite.
- [E. 1816.] Boss in field s. of *Martha Gullet*, Langness : Camptonite.
- [E. 2090.] Dyke on shore 35 yds. n. of *Prison*, St. Patrick's Isle, Peel : Camptonite.
- [E. 2117.] Dyke? s. bank of Glen Meay, above pumping rod of old mine : Camptonite?
- [E. 1971.] Boss, in field 200 yds. N.20°E. of *Dourlish Cashen*, Dalby : Camptonite, sheared.
- [E. 1815.] Dyke, 120 yds. s. of wall at *Martha Gullet*, Langness : Augitic Camptonite.
- [E. 2120.] 8 ft. dyke, arch of Stack, 450 yds. N.E. of Port Soldrick ; Augitic Camptonite.
- [E. 1970.] 6 ft. dyke on beach opposite Ballynalargy, Dalby : Augitic Camptonite with mica?
- [E. 2088.] Dyke at low-water, 200 yds. E. of Port Soldrick : Augitic Camptonite?

"It is necessary to group together the rocks belonging to these two types, as there are no sharp lines of division between them. Indeed this is the case with the majority of the Manx dyke-rocks. If a sufficient number of dykes be examined it is possible to obtain gradations between almost any two types.

"Langness may be regarded as a typical locality for the diorites, but they are also seen in many other parts of the Island, as, for instance, at Garwick and near *Niarbyl*. Although they do not precisely correspond with Rosenbusch's group of camptonites they have so many points in common with the genuine camptonites of the Island that they may all be considered together.

¹ Quart. Journ. Geol. Soc. xlvii. pp. 432-450 ; and *Yn Lloar Manninagh*, vol. 1, pp. 337-348.

² Names of places in italics are those not given on the one-inch map.

"The characteristics of all these rocks is the abundance of hornblende, which occurs in idiomorphic crystals, in which Mr. Teall noticed the following planes (110), (010), (100), and (001). Both brown and green varieties are common in the same rock, and the scheme of pleochroism is as follows, α light brownish or greenish yellow, β and γ darker brown, brownish green, or dark green. The brown variety has frequently a border of deep green mineral at its ends and sometimes at its other edges. This border passes readily, and the rest of the mineral a little less readily, into chlorite. Epidote is also frequently developed at the expense of the hornblende. In some rocks the hornblende is converted into a brown granular product, which is generally isotropic; and when the shape and cleavage are not well preserved, it is not easy to affirm the presence of hornblende in the rock.

"In the camptonites the hornblende crystals are usually smaller, and in some cases, as in slide [2090], they occur as a mass of slender needles, which penetrate the feldspars of the ground-mass in an ophitic fashion.

"Augite is not always present, but in many examples a few crystals occur, and in others the augite becomes a very important constituent. It belongs to the colourless variety known as malacolite, and it is sometimes little altered. It may usually, however, be seen in various stages of conversion into pale green uranite, and this mineral is sometimes to be found enclosed in the compact hornblende [1941]. The normal rock at Braggan Point, Garwick, bears augite in abundance with but little brown hornblende, but where it is penetrated by an acid vein there is abundance of brown hornblende in it.

"A few much-decomposed rocks have been classed as augitic camptonites, as hornblende is not very plentiful in them, while they contain pseudomorphs in carbonates and chlorites which appear to have been augite. These occur porphyritically.

"Mica is not a common mineral in these rocks, but it occurs in a few examples which will be referred to later on.

"The feldspars in all these rocks are much obscured by the development of secondary minerals, particularly epidote, calcite, and sericite. Both orthoclase and plagioclase (apparently oligoclase) are present, the latter in slight excess in the coarse rocks, but in no great quantity in the finer ones, while it is often altogether absent. In the coarse rocks the feldspars are in rounded grains, but in the fine rocks they are in stumpy prisms like those generally met with in lamprophyres. In both cases they are set in a small residuum of interstitial quartz, and secondary quartz is generally associated with a considerable mass of chlorite.

"Iron ores are not very abundant, but both magnetite and ilmenite are present, the latter frequently passing into leucoxene.

"Epidote and zoisite are both common minerals, the former being yellowish-green, the latter almost colourless. They appear to have arisen chiefly from alteration of the feldspars.

Texture.—The idiomorphic hornblende is the characteristic feature of all the rocks. In the coarse rocks the texture is granular; in the finer grained it is more like that of Rosenbusch's lamprophyres, in the crowded mass of small feldspars whose interspaces are filled with only a small quantity of interstitial quartz.

Veins.—In the specimen [2538.] which is traversed by an acid contemporaneous vein, this latter consists of small, well-twinned plagioclase feldspars and orthoclase, with much interstitial quartz and epidote; the orthoclase is associated with micropegmatite.

Decomposition.—The decomposition of this class of rocks is accompanied by the production of much calcite and other carbonates. The form of the ferromagnesian constituents is generally well preserved, but that of the feldspars in the ground-mass is utterly obscured and lost.

Shearing.—The specimen [1971.] is very interesting, as it presents the effect of shearing in an undoubted camptonite. The plagioclase feldspars are idiomorphic, and have not suffered much from the shearing. The “eyes” are formed of brown hornblende crystals, to which deep green hornblende has frequently been added at the ends. The sides and ends are sheared off, and “tails” of chlorite formed, in which, however, there are grains of brown hornblende, actinolite needles, and occasionally a little tremolite. Other eye-like patches of chlorite have probably had a similar origin, as they sometimes contain a little brown or else pale green (uralitic) hornblende.

Hornblende Mica-Traps.

“Between the camptonites just described and the true mica-traps come the following rocks, which bridge over this gap:—

[E. 2391.] Dyke or boss, cliff on S. side of Port Groudle (see p. 152).
Hornblende mica-trap.

[E. 2504.] Dyke or boss, crags on golf-links S. of tram-station, Port Groudle (probably prolongation of [2391]). Hornblende mica-trap.

[E. 1810.] Dyke, north end of *Gullet ny Guir*, Langness: much altered.
Hornblende mica-trap.

“The chief constituents are brown and green hornblende, the latter generally predominating, and the former having a greenish tinge. Sometimes the idiomorphic crystals are brown at the centre and grade outwards into green borders, and outside this is often a fringe of actinolitic hornblende. The colour scheme is the same as that already given. Biotite varies in quantity, but is present in all this group, or rather pseudomorphs in chlorite and opacite occur, undoubtedly after this mineral. The ground-mass is made of idiomorphic crystals of plagioclase, and some of orthoclase, both of which in the Port Groudle specimen are surrounded and filled in with a beautiful growth of micropegmatite; a little quartz is also present in that example. In other examples no quartz is present.

Biotite Mica-Traps.

[E. 1901.] Dyke at E. side of *Chasms* near Port St. Mary.

[E. 1957.] Dyke same as last; in cliff at N. side of Kioney Ghoggan. (See p. 176.)

[E. 2091.] 5ft. dyke, foreshore W. end of St. Patrick's Isle, Peel.

[E. 2123.] Interior of boss, at *Cave*, N. end of Wills Strand, near Peel.

[E. 2093.] Dyke at old slate quarry; Contrary Head.

[E. 2119.] 2ft. dyke, cliff S. side of *Laider*, Contrary Head.

[E. 2399.] Dyke, road below Neary Farm, Glen Auldyn.

[E. 2470.] 8ft. Dyke, stream-bed under bridge below Engine House, Glen Agnecash.

“A ‘uniaxial’ brown biotite is the characteristic phenocryst in these rocks. Usually it is pale internally, but with a deep and occasionally a black border. Internally they are frequently zoned. The ground-mass in some cases is like that of a microgranite and [1901] consists of small crystals of orthoclase and plagioclase, mica flakes, and interstitial quartz. In other cases it is made of larger feldspars optically enclosing small biotites without any interstitial quartz. No useful purpose would be served by grouping these rocks as Minettes and Kersantites. When these rocks decompose only the forms of the minerals are recognisable. Chlorite and calcite are abundantly produced. The rocks are not as a rule much sheared.

“There remain a few rocks with somewhat the habit of mica-traps but in which no biotite remains. Occasionally good-sized porphyritic crystals of a white mica may remain, and much muscovite in the form of minute flakes

in the ground-mass, together with chlorite and felspar, and generally secondary quartz. Idiomorphic crystals of dolomite are frequent in the ground-mass of [1947]. The rocks are all considerably sheared.

[E. 1946.] Dyke, on shore E. side of *Chapel Bay*, Port St. Mary, 50yds. S. of first rocks.

[E. 1947.] Dyke : same locality as last, 85yds. S. of first rocks.

[E. 1949.] Dyke : in recess at *Purt Beg*, St. Ann's Head.

[E. 2539.] Dyke, coast about 150 yards N. of Gob ny Garvain, Maughold.

[E. 2112.] Dyke ? gutter S. of *Ballagarmin*, near Arbory, below spoil-heap.

Rocks bearing Porphyritic Augite.

"A group of rocks occurs which is characterised by bearing large idiomorphic crystals of malacolite. One or two examples contain also a considerable proportion of hornblende and mica, and so have affinities with the augitic lamprophyres, but the rest are devoid of these minerals, so that it will be best to consider them all under the head of porphyritic diabases. The following descriptions of slides will illustrate the characters of this somewhat diverse group.

[E. 1942.] 12ft. dyke : Cliff at *Hango Broogh* (near St. Michael's Island) Langness.

A medium-grained, dark green, massive, crystalline rock.

Micro.—The prominent feature is the large phenocrysts of augite, of which there are good cross-sections showing (110), (100), (010), and (001), and another basal plane : colourless to pale yellow-brown, with only very slight pleochroism : converted along cracks into brown, highly refracting, fibrous, slightly anisotropic substance. Next in abundance is mica, in long flakes, all converted into chlorite, and the usual darker fibrous semi-opaque substance. Then come small idiomorphs of hornblende, brown and fresh. There is also much sphene, which seems to have been derived from ilmenite, of which there is still a considerable quantity left. The felspars, as a rule, are not perfect, and are slightly elongated, muddy, altered, and often much converted into sericite ; they are generally well twinned. Ground-mass consists mainly of chlorite and quartz, both secondary. The affinity of the rock appears to lie with the lamprophyres and mica-traps, in its three porphyritic idiocrysts, and to some extent in its ground-mass. Another part of the same dyke is represented by slide [E. 1943.], which showed the above features, with some modifications.

[E. 2833.] 8ft. dyke : Crogga Glen, North of *Lhergey Farm*, Port Soderick.

Porphyritic diabase, with augite phenocrysts.

Micro.—This belongs to the type with large porphyritic augites, accompanied by hornblende and some mica. The augites are idiomorphic ; malacolite, somewhat rounded and zoned with opacite belts ; they are twinned and occasionally grouped ; a little brown hornblende is sometimes contained in them. Brown hornblende is not very abundant or well-formed : in long crystals, the ends passing into dark green, and that into pale green hornblende and actinolite. A few chlorite replacements of brown mica occur, in which a little of the original mineral is still preserved. Iron ores are not at all abundant, and are almost entirely converted into leucoxene. The ground-mass is of not much elongated plagioclase felspars, set amongst abundant chlorite, the felspars much altered into a white opaque substance, with only slight reaction on polarized light. There is a little secondary quartz.

- [E. 1972.] Boss in large quarry at Poortown, near Peel.¹

An almost black rock, showing numerous fairly conspicuous black crystals in a fine-grained dark green matrix.

Micro.—This rock is made up largely of phenocrysts of the same augite as in [1942], but these are associated in groups, idiomorphic externally, allotriomorphic internally. A considerable amount of chlorite is associated with these patches, as though made from augite. The ground-mass is a tangle of lath-like plagioclase, with much chlorite and iron ores, mainly ilmenite, freely converted into sphene, and of this there is a fair quantity scattered through the chlorite and elsewhere in the rock. A little actinolite is associated with the chlorite.

This rock probably belongs to the same type as [1942], but represents a slight concentration of the augites in rather less of the ground-mass. To name it is difficult, but it may be placed with the Augitic Lamprophyres.

- [E. 1980.] Horse Rock, at foot of cliff at Kioney Ghoggan (see pp. 175-6).

A dark green rock, slightly sheared, with conspicuous black crystals in a fine-framed green matrix.

Micro.—This rock clearly belongs to the same type as [1942] and [1972]. In it the augite is in clusters, and is converted into a pale green uraltite, slightly fibrous and polarizing as though more compact than usual. The clusters are sheared off at their ends, and pass into chlorite, with which a little epidote is associated. The feldspars of the ground mass are of fair size, well twinned, and tending to arrange themselves parallel to the general shearing. As usual, the ilmenite passes into sphene. Where the ground-mass is most sheared it passes into an aggregate of quartz and chlorite.

- [E. 2089.] Dyke at Chicken Rock, off The Calf (p 173.).

A porphyritic diabase (augite and feldspar).

Micro.—In addition to large uraltized augites, as in [1980], the slide contains porphyritic plagioclases, which are well twinned and in which the chief alteration is into epidote and chlorite. The minutely granular ground-mass as usual contains feldspar, chlorite, quartz, and calcite. The fairly abundant iron ores are almost converted into sphene.

“The following slides also bear more or less resemblance to those above described, and may be classed with them.

- [E. 1948.] 9ft. dyke : east corner of *Purt Beg*, St. Ann's Head.

- [E. 1944.] Dyke at S.E. side of recess next north of *Toultfoggy*, near Port St. Mary.

- [E. 2483.] 8ft. dyke, with clusters of augites ; cliff *N.* of *Dreem-e-jeeskaig*, Bulgham Bay.

Other Porphyritic Diabases.

“A large number of the ‘greenstone’ dykes, though still retaining traces of their porphyritic structure are too much decomposed to show their original composition, and therefore cannot be assigned to any particular group. In these rocks the feldspar is frequently the only original mineral which can still be recognised. The three following slides will suffice to illustrate these rocks.

- [E. 1974.] Boss or dyke : headland *N.* of *cave*, Wills Strand, *N.* of Peel ; a medium-grained dark-green massive rock.

¹ This rock has been previously described by Mr. B. Hobson. Op. cit.

Micro. There are a few porphyritic feldspars, generally simply twinned and sometimes in cross-twins, and with internal alteration to muscovite as though they were potash feldspars (orthoclase). The plagioclase is in long laths, with subophitic arrangement, associated with chlorite, calcite, and some quartz, the bulk of the latter being interstitial and apparently secondary. Iron-ores plentiful, and apparently chiefly magnetite, as there is little or no leucoxene. A little apatite is present. The feldspar is too much altered to show the extinction angles.

"This diabase may be taken as the type of the Manx greenstones; in many respects it is like the North Welsh and Cornish set, of post-Upper-Silurian date.

[E. 2114.] 10 ft. dyke: cliff under the school-house, Port St. Mary. A crushed porphyritic diabase.

Micro. Porphyritic feldspars plentiful, but completely converted into a sericitic tangle; a mere trace of twinning remains. Ground-mass of small twinned feldspars, secondary quartz and calcite, with some chlorite. Some of the carbonate tangles may represent augite, but nothing can be made out of them.

[E. 2134.] Middle of Boss: quarry 200 yards s. of of high road near Cronbane, between Kirkmichael and St. John's (p. 137).

A porphyritic diabase, somewhat abnormal, and rather acid.

Micro. The undoubted feldspar phenocrysts are converted into granular aggregates of quartz and feldspar, which are floating in a great mass of chlorite; the rock has been much sheared; sericite is present in quantity. Some of the phenocrysts are like orthoclase.

[E. 2390.] ¹ Boss or dyke intrusive in crush-conglomerate: quarry at Kerroo Moor, Sulby.

Micro. This rock, which has macroscopically the appearance of a diorite, consists of large irregular masses of plagioclase (oligoclase or andesine), with both albite and pericline-twinning; the edges are very irregular. The granular matrix is chiefly made up of feldspar, but it contains a certain amount of quartz, which is associated with calcite, often in large grains. Chlorite is now the sole representative of any ferromagnesian mineral which may have been present; it occurs in masses in which the fibres are arranged in one direction so as to yield straight extinction. The rock is an altered diorite or dolerite, most probably the latter. It is this rock which has affected the contact alteration of the crush-conglomerate described at p. 105.

The following dykes, among others, may be placed under this heading:—

[E. 1981.] Dyke with large sheared crystals: *Halfway Rocks*, s. of Port Erin (p. 172). (Plagioclase feldspar the most important porphyritic constituent.)

[E. 1960.] 8—10 feet sheared dyke: coast 120 yards s. of *Clet Aldrick*, s. of Port Erin. (Plagioclase feldspars alone remain.)

[E. 2003.] Dyke: in grits, on *Carnanes*, 300 yards s. of Ballarock, near Fleshwick. (Feldspar phenocrysts, probably oligoclase.)

[E. 2032.] 1 foot dyke: cliff at *Chastal Voar*, Contrary Head.

[E. 2098.] Boss in field w. of road, 1100 yards s. of *Barnell*, Kirk Patrick. (See p. 162 and Fig. 41).

[E. 2821.] 12 ft. dyke: cliff 300 yards s. of *Yn Scregganagh*, Clay Head.

[E. 2825.] Dyke: road 100 yards n. of *Thalloovell*, St. Mark's.

¹ Reprinted from Quart. Journ. Geol. Soc. vol. li., p. 596.

Decomposed Greenstones.

"We next proceed a stage further in the degree of alteration, and find the greenstones, even where not greatly sheared, in a condition such that scarcely a trace of the original structure remains. In the field, in small exposures, the dykes of this kind were very difficult to distinguish from the hard bands of fine-grained greywacke which sometimes occur isolated among the striped slates intermediate between the Barrule Slates and the grits of the Manx Series.

A large number of slides were therefore cut and examined to aid in the mapping of these rocks; the five following examples will show their general characters:—

[E. 1945.] Dyke at landing stage in inner harbour. Port St. Mary. Light-grey fine-grained diabase.

Micro. A very fine-grained rock in which twinned needles of felspar are embedded in a fine ground-mass of felspar and chlorite; pyrites is present, and carbonates, probably of lime. Traces of flow-structure in direction of phenocrysts. Ferromagnesian minerals not observable. A fine aggregate of white mica.

[E. 1951.] 1 ft. dyke, apparently intruded into a larger greenstone dyke 8—10 ft. thick. Cliff 122 yards s. of *Clet Aldrick*, s. of Port Erin. Greenish-grey highly schistose rock.

Micro. Fine-grained ground-mass of felspar and chlorite, embedding small phenocrysts of felspar, not quite so much elongated as in case of [1945] though the rock is clearly of the same type. There are some traces of flow-structure and also shearing. Some rather large slivers of chlorite occur, and idiomorphic dolomite crystals are very abundant.

[E. 1962] 20 ft. band: Cliff at *Fheustal*, Niarhyl Bay. Medium-grained grey rock; decomposed diabase.

Micro. Shows igneous structure; possibly was porphyritic; little or no shearing perceptible. A confused aggregate of quartz, calcite, chlorite, and more sericite than usual; limonite; a few small felspars.

[E. 2099.] Boss or dyke: Coast at end of Gob y Deigan, N. of Peel. Decomposed diabase.

Micro. Larger felspars altered to masses of sericitic tangle; ferromagnesian mineral altered to chlorite films, and generally with parallel arrangement and occasional pleochroic halos. Calcite and quartz freely developed. Igneous structure observable. No marked foliation in slide.

[E. 2401.] Hard bed: Quarry at *Laurel Mount*, Lézayre. Grey rock, sheared, with calcareous spots in shapes of crystals, and other pseudomorphs chiefly in chlorite; decomposed ophitic diabase.

Micro. Apparent relics of ophitic structure are seen, the felspars altered into calcite, the ferromagnesian mineral into chlorite; phenocrysts in carbonates and chlorite which look like olivines; apparently felspar phenocrysts are also present, and a little ilmenite not much altered.

Among the numerous other slides of this character in the Survey Collection, the following are mentioned to illustrate the wide distribution of these dykes in the Island:—

[E. 2121.] 8 ft. dyke (coarse-grained part): in arch of Stack, 450 yards N.E. of Port Soldrick.

[E. 2113.] *Atnagh* Stream, N. side of road-crossing to Glen Helen.

[E. 2129.] Dyke (loose blocks): W. side of Lhargee Ruy, Greeba, 90 yards W. of road W. of U. of Ruy.

E. 2197.] 10 ft. dyke: E. side of Colby Glen, in plantation above weir.

Schistose Greenstones.¹

When the dykes are not only decomposed, but crushed down also, and plated out by shearing, they ultimately take the form of calc-chlorite or calc-sericite schists which, as previously remarked, present few or no distinguishing features under the microscope. The mode of occurrence of dykes of this character in the field is illustrated in Figs. 43 & 47. The petrographical notes on the following slides are arranged to illustrate the progressive stages in the obliteration of the igneous structure.

[E. 1979.] 15 ft. sheared dyke. Cliff 100 yards N. of *Creg ny Jaghee*, Calf Sound: Grey schistose rock; originally a porphyritic diabase.

Micro. Phenocrysts, still undecomposed, of twinned felspar, with refraction index higher than balsam (?labradorite), often grouped, broken, sheared, and in "eyes." Small dark patches, rich in rutile, probably from alteration of titaniferous iron-ore. Rather large slivers of chlorite. Ground-mass of chlorite, calcite, felspar, and quartz, with pyrites.

[E. 2428.] Dyke (one of several): *Glen Crinn* (branch of Glen Auldyn), 500 yards N. of mountain-road.

A rock with dark grey matrix, sheared, with greenish chloritic folia, and porphyritic groups of crystals; probably originally an abnormal porphyritic diabase, now a chlorite schist.

Micro. Chlorites rather large; small porphyritic felspars (plagioclase and oligoclase) just visible, in groups; some of the chlorites suggest micas, and it is possible this may be an altered mica-trap, but the small amount of calcite present is decidedly against this, and also marks it off from the other altered rocks.

[E. 1977.] 9 ft. dyke in cross-cut of copper-mine, Langness Point.

Rather pale green somewhat schistose rock; a calc-chlorite schist, almost certainly a sheared camptonite.

Micro. The large masses of ferruginous carbonate probably represent hornblende; and those of chlorite sometimes associated with calcite probably represent augite; and possibly a little mica may have been present. Calcite and chlorite with some quartz grains constitute the sheared ground-mass.

[E. 2192.] Dyke?: quarry at *West Folieau*, near Ramsey.

Sheared greenish rock with pseudo-vesicular structure; diabase, sheared to a calc-chlorite schist.

Micro. Phenocrysts in granular carbonates with new growth of calcite and quartz at edges under influence of shearing; these form "eyes" and are much sheared off at the ends, graduating into the ground-mass. The latter is a fine schistose aggregate of quartz, carbonates, sericite, and opacite which appears to represent an iron-ore.

[E. 2194.] Dyke?: beach 40 yards N. of jetty at Port Lewaigue, near Ramsey.

Rock similar to [2192].

Micro. Like [2192], but appears to have been moved subsequently to decomposition, as the carbonate granules are dispersed, and the chlorite slivers are puckered and have a strain-slip cleavage. This appears to represent very advanced shearing and decomposition.

¹ From this point onward to the end of the chapter, Prof. Watts is not responsible for the general notes introducing and connecting his descriptions of the slides. G. W. L.

[E. 2926.] Sheared dyke : Black Rocks, Kentraugh, Bay ny Carrickey.

A buff-grey streaked schist.

Micro. A schistose mass of sericite, chlorite, and in places cryptocrystalline quartz-mosaic, and spots of iron-ores; carbonate also in spots. Absolutely no trace of igneous structure remains.

To conclude the account of the sheared greenstones, we give the following description and analysis from the notes of the present director of the Survey, Mr. J. J. H. Teall, who undertook the investigation of a few specimens of these rocks collected soon after the commencement of the survey of the Island in 1892 :—

“[E. 1965.] 20ft. dyke : Cliff at n. side of Da Leura, s. of Niarbyl Bay. A compact pale-grey slaty rock.

Micro. A microcrystalline aggregate of quartz or felspar (or both), sericitic mica, chlorite and carbonates.

“In the hope that the determination of the chemical composition might throw some light on this rock, I analysed it, with the following result :—

	Per Cent.
Silica - - - - -	65·4
Alumina - - - - -	16·2
Ferric oxide - - - - -	3·5
Lime - - - - -	4·2
Magnesia - - - - -	1·6
Potash - - - - -	1·25
Soda - - - - -	1·9
Loss on ignition - - - - -	5·7
	99·75

“This does not help one to interpret the rock, and I must leave its original nature completely undetermined.”

Among other examples of the sheared greenstones of which slides are preserved in the Survey collection are the following :—

[E. 2125.] 2ft. dyke : cliff w. of *Banner Rock*, Santon.

[E. 2820] 3ft. dyke : cliff n. side of headland n. of Staiden, Santon.

[E. 2193.] Dyke : cliff e. side of Tableland Point near Ramsey.

[E. 2482.] n. side of boss forming *Carriack* low-water reef, Ramsey Bay ; (a sericite-chlorite schist, more acid than usual).

[E. 2126.] Dyke : quarry in coppice on e. bank of stream, 300yds. above *Spoat Vane*, near Kirk Michael.

[E. 2127.] Sheared dyke or boss : old quarry in plantation at s. side of Ballacoshnahan, near Kirk Patrick.

[E. 1966] Hard band : crag in *Balleby Glen*, 600yds. e. of high road, near Dalby.

[E. 1958.] Sheared dyke or boss : coast 150yds s. of *Kione Halby*, Calf Island.

Metamorphosed Greenstones and Actinolite Traps.

We have next to deal with the alteration of the older dyke-rocks, by later intrusions and by the obscure causes which produced the curious metamorphism of the sedimentary rocks described in a former chapter (pp. 108-14).

The effect of later intrusion is best seen in the vicinity of the *Dhoon Granite*. As previously described (p. 142), this granite has burst through slates already traversed by greenstones, and has sent out elvans which intersect these older dykes, as shown in Figs. 35, 36 and pp. 128-30. Several of these greenstones are exposed in the cliffs between Port Cornah and *Dhoon Bay*, immediately to the eastward of the granite ; and the first two slides

described below are from the dykes of this locality. The third slide is from an example at contact with an elvan on the same coast $1\frac{1}{2}$ miles farther north, and the fourth from a dyke in the vicinity of the Foxdale Granite.

[E. 2476.] Altered greenstone dyke, $\frac{1}{2}$ in. from contact with 15ft. elvan (see p. 130, Fig. 36) : cliff s. side of Barony Hill.

Micro. There appear to be traces of twinned feldspars, one or two suspiciously fresh, but the rest converted into several minerals : sphene, epidote, and zoisite are very abundant, and all embedded in a ground-mass of brown mica ; a little uraltic hornblende is present. Apparently a thermo-metamorphosed greenstone very highly altered.

[E. 2524.] 3ft. altered greenstone dyke, on n. side of intersection with elvans ; same locality, etc., as last.

Micro. Pale fibrous porphyritic uraltite in abundance ; ground-mass—quartz, feldspar (!), chlorite, and brownish hornblende, with abundant sphene. Probably one of the augitic diabbases, now thermo-metamorphosed.

[E. 2480.] 8 to 10ft. sheared greenstone dyke, at junction with elvan : cliff at Traie ny Uainague, Maughold. (See p. 123. Fig. 35.)

Micro. Original igneous structure preserved : a quartzose diabbase, with small feldspar phenocrysts : iron ores preserved, but calcite alteration, and much chlorite often in rather large patches. A small amount of brown mica has been developed. A vein of porphyritic rock with much larger feldspars is seen in the fine-grained rock—almost andesitic in habit.

[E. 2828.] Sheared dyke : stream 120 yards s.w. of *Glendhoo* Farm, Doarlish Head, near Foxdale.

Micro. A calc-sericite schist, finely foliated : iron ores preserved : much calcite ; chlorite in broad streaks, edged with small flakes of brown mica, which occurs in larger crystals in the body of the rock, often crossing the foliation-planes, but evidently developed *in situ* ; ground-mass of quartz and feldspar (!) A thermo-metamorphosed sheared diabbase.

We have now to discuss the changes in the mineral structure of the greenstone dykes where they traverse the belt in which the slates have undergone their most severe alteration.

As the following descriptions will show, the dykes in this belt are often completely metamorphosed ; and a characteristic feature of this kind of alteration is the abundant development of actinolite and epidote in the dykes, which appears to be correlative with the development of garnet and a chloritoid mineral in the accompanying slates of the belt.

Starting from the north-east, the actinolite traps first become conspicuous in the vicinity of Snaefell (p. 139), and may be thence followed across the watershed into the head of the Baldwin Valley. They are seen again on the northern slope of the central valley n. of Crosby (p. 158), and on the southern slope opposite Greeba (p. 168), whence they are continued into the highly schistose area around the old Cornelly mine (p. 168). They are probably prolonged into the head of the Silverburn Valley and a little farther south-westward, but are inadequately exposed and have been less closely investigated there.

The petrographical descriptions and list of slides given below as example of these actinolitic-traps are placed in the order of occurrence as above outlined.

- [E. 2389.] 3ft. Actinolitic dyke : stream-bed 120 yards below foot-bridge near Block Eary, n. of Snaefell.

Micro. An exceptional actinolite trap, with large masses of secondary quartz growing among the chlorite : a little epidote and actinolite apparently formed subsequently to the shearing and often crossing its direction : pyrites present. There are a few phenocrysts which remind one of the large augites of the augitic diabases. An altered diabase, now an actinolite-schist.

- [E. 2407.] 6ft. palish dyke : same locality as last, 380 yards above foot-bridge.

A quartz-chlorite schist with epidote and actinolite ; an altered diabase more acid than usual.

- [E. 2402.] Sheared dyke : *Tholt-e-Will* stream, 130 yards above boundary of Hotel grounds, w. of Snaefell.

Micro. Evidently a diabase which has been much sheared (probably twice) and undergone a slight amount of actinolitic change. Traces of what appear to have been idiomorphic of felspar are present, but the conspicuous elements are slivers of chlorite, rather large and with strain-slip cleavage, and granules of calcite inside and outside the chlorite. The main ground-mass is granulitic quartz with chlorite, but apparently no felspar. The iron-ores are partly converted into leucoxene. A little sheafy actinolite is developed at the expense of the chlorite.

- [E. 2388.] Sheared dyke : stream-bed 600 yards E. 10° S. of Snaefell lower hotel.

An actinolite-chlorite-schist.

Micro. A chloritic and quartzose schist, with perhaps secondary felspar. In the masses of chlorite are idiomorphic of epidote, zoisite and sphene (probably from ilmenite), and these masses pass into bundles of actinolite with compact shafts and branching ends, generally conforming with the foliation, but often across it. Actinolite needles run into the secondary quartz. No carbonates are present.

- [E. 2420.] Altered rock, ? slate or dyke : crags 500 yards S.S.W. of *Carnau Bane*, Beinn-y-Phott.

Micro. A garnet-hornfels : a yellowish-grey rock with an appearance of false bedding or shearing, some bands being rich in large dark micas and other minerals. This has all the appearance of an injected junction of the actinolite-trap type and a sediment. One side consists mainly of granular quartz, '001 inch, '005 inch, '015 inch, with brown mica and an occasional bit of sphene, but with occasional layers (? injections) of a more basic rock richer in brown mica, sphene, and epidote. Beyond a quartz-vein the rock is merely a thermometamorphic greenstone of actinolite-trap type, full of brown mica, chlorite, hornblende, epidote, sphene and garnet. There are, however, seams of granular quartz in it, like seams of the sediment between injection veins. Actinolite-trap and sediment, contact ?

- [E. 2392.] Dyke : at junction of east branch of stream N. of Ingebreck.

A greenish-grey rock chiefly made up of radiating actinolite.

Micro. Of the usual character, but with great abundance of actinolite, often springing from crystals of compact hornblende ; in the actinolite there is a warm brown mica freely developed, with sphene and epidote ; there is little ground-mass, and an absence of carbonates and felspar. An actinolite-schist with brown mica.

- [E. 2826.] 3 ft. much-altered dyke : East Baldwin River, 150 yards w. of Creg-y-Cowin farm.

An actinolite trap with abundant brown mica and epidote.

Micro. This is a coarsely crystalline rock with schistose structure. Where ground-mass is present it is of the usual finely granular quartzose type. Chlorite is largely present, and passes into actinolite in places, but not into massive hornblende. Well-crystallized epidotes are developed in great quantity in the chlorite, and also much sphene and a little calcite. The other common constituent is a brown mica in large compact crystals, also not conforming to the shearing.

"The impression from the three above-described rocks is that the brown mica and epidote have been produced independently of the shearing, and after it; and their production is just like that known as the result of thermo-metamorphism" [w.w.w.] There is, however, no known outcrop of igneous rock, except in small dykes, within three or four miles of the localities [G.W.L.]

- [E. 2823.] 10 ft. altered dyke : Cronk Breac, N. of Braid, near Crosby.

Micro. Radiating masses of actinolite abundant; a little pale brown mica, developed at expense of chlorite; much sphene and some epidote; small scattered crystals of plagioclase, considerably decomposed, associated with chlorite and quartz.

- [E. 2827.] Altered dyke : Ellerslie Glen, S. of Crosby, 200 yards S. of dam.

Micro.—Actinolite-trap, with igneous structure no longer observable; epidote in great quantity and often idiomorphic; a very little radiating actinolite in ground-mass apparently mostly of granular quartz and some secondary feldspar. Groups and single large crystals of a twinned chlorite occur. Zoisite appears also to be present.

- [E. 2824.] Dyke; corner of field N. of Cooulingill, W. of Crosby.

Micro.—Actinolite-trap of advanced character, with great sheaves of bluish green fibrous hornblende and more fibrous actinolite; sphene, epidote, and iron ores in small grains and not so abundant as usual.

GRANITIC ROCKS.

Turning now to the consideration of the more acid intrusions of pre-Carboniferous time, we have first to deal with the two principal granite-masses of the island—that of the Dhoon in the north-east, and that of Foxdale in the middle of the slate massif. As elsewhere noted, both intrusions crop out in the neighbourhood of the central stratigraphical axis of the Manx Slates (see Fig. 29, p. 84), and their elvans run parallel to this axis, and are confined to a comparatively narrow belt on both sides of it. Through more finely-grained, these elvans preserve the distinctive petrographical characteristics of the two granites for a few miles each way from the main intrusions, but with closeness of texture increasing with the distance until finally they become difficult to discriminate.

The two granites differ considerably in mineralogical composition, and also in mode of occurrence and in structure. The Dhoon Granite, as previously described (p. 144), appears to form a rude column with steep walls, while the Foxdale mass shelves gradu-

ally beneath the slates and is probably more or less laccolitic in outline. Both granites are to some extent deformed in places at the margin by shearing movement, but this deformation (see Fig. 38, p. 143) is much more conspicuous in the Dhoon than in the Foxdale intrusion. There is no distinct evidence as to the relative age of the two intrusions, but it seems likely that the Dhoon Granite is the older.

The Dhoon Granite and its Elvans.

The local details respecting the outcrop of the granite have been given in Chap. iv., pp. 142-4. Its petrographical characters will now be described.

[E. 2897.] Granite; large quarry at Dhoon.

Macro. Grey granite with patches of brassy mica, white felspar, and blue (opalescent) quartz; black minerals fill up the angles between the white ones.

Micro. The conspicuous character of this rock is the presence of porphyritic crystals of plagioclase (oligoclase) $\frac{1}{2}$ inch (6 mm.) long. Smaller phenocrysts both of plagioclase and orthoclase occur, generally well-formed and with good angles and edges; they are, however, very impure and are really a mass of other minerals—muscovite, quartz, epidote, and chlorite, in a ground-mass of felspar substance; this character should permit of the identification of the elvans from this mass, as the Foxdale granite itself has singularly pure felspars. Irregular patches of biotite are common, generally with pleochroic halos, and "embroidered" with quartz and iron ores. Epidote and iron ores are often closely associated with the biotite. Sphene in fair-sized grains is not uncommon, and leucoxene occurs looking very like sphene. A few phenocrysts of quartz also occur, strained and granulated and occasionally containing felspar crystals. The ground-mass is of granular quartz associated with minute biotite flakes, and there are irregular patches of muscovite which do not appear to be original. The chlorite present appears to be due to the decomposition of biotite. There is generally a little new growth round the felspars. There is a little, but not much, white mica in the ground mass.

The rock belongs to the porphyritic *micro-granite* series, rather than to the true granites.

[E. 2381.] Granite; same locality as last.

Micro. General features like [2887], but with a larger proportion of small felspars in the ground mass; and biotite is in larger groups, associated with epidote. The association of sphene with iron ores suggests derivation from ilmenite. Zoisite $\frac{1}{12}$ to $\frac{1}{5}$ inch long. In the quartz-bodies several adjacent granules separated by veins of mosaic behave as a whole optically, and there are injections of mosaic also inside the grains.

[E. 2488.] At junction of granite with flags: moorland, N. of Ordnance station, W.S.W. of Ballelin, Dhoon.

Crushed micro-granite.

Micro. This appears to be a crushed form of the Dhoon Granite. The felspars are brecciated, and have lost their sharp outlines; the quartz is more freely granitized; the ground-mass is lineated, and contains brown and white mica and chlorite in greater abundance, while all the larger biotites are converted

into chlorite with pleochroic halos. One part of the rock appears to be so crushed out that the micaceous feldspars appear to have been incorporated with the ground-mass.

[E. 2487.] and [E. 2898.] Granite-vein in altered flags : northern edge of granite on Barony Hill.

Micro. These slides show thin veins of microgranite injected into schist, and probably crushed out with it. The veins have lost most of their characters. The ground-mass is rolled out and associated with much muscovite, sometimes in fair-sized grains, and some rutile is present. In [2898] feldspar phenocrysts are occasionally recognisable, but generally smashed ; and quartz phenocrysts also occur.

The slate at the margins is much altered and is converted into a muscovite-biotite schist with abundance of (probably) small feldspars and quartz. A few small garnets are present, mostly occurring along particular bands.

The elvans which spring out from the eastern margin of the Dhooon granite are described at pp. 127-30. The following slides of these rocks are arranged in the order of increasing distances from the granite. The dykes frequently show a platy semi-schistose structure due to shearing, which is admirably brought out in some of the slides. In the field, these elvans may be distinguished from the other microgranites by the presence of small roundish grains of opalescent blue quartz.

[E. 2900.] Southern elvan : Barony Hill, Dhooon.

A fine-grained micro-granite or microcrystalline quartz-porphry.

Micro. Orthoclase, plagioclase and quartz phenocrysts, the latter strained and granulitized, but still sometimes with trace of the bi-pyramidal form : biotite aggregates, also with the usual forms and pleochroic halos, and a number of small scattered garnets. The ground-mass is a minute micro-granite, with feldspar, quartz and very abundant muscovite, with a lamination which is at first not conspicuous, but which corresponds with that of some of the biotites. The feldspars are a little cleaner than usual, but the bulk of them are full of muscovite.

[E. 2901.] Same elvan as last : shore below Barony Hill.

Micro. Like [2900] but with less feldspar and much less biotite, but abundant quartz : feldspars fairly clean. There is one perfect crystal of *microcline*. The ground-mass is much more sheared, and contains abundant muscovite, Carlsbad feldspar, and quartz : a few small garnets.

[E. 2386.] From the elvan in a quarry at the crest of the cliff-slope ; shows similar features to the last, but with large garnets and sphene, and with microcline in fair-sized grains, and with the addition of phenocrysts of micro-pegmatite. No biotite is present.

[E. 2902.] Same elvan, and same locality as [2901], at junction with ' green-stone ' dyke (see p. 130, Fig. 36).

A quartz-sericite schist or quartz-porphry rolled out.

Micro. A perfect quartz-sericite augen-schist, with quartz granulated and torn out : feldspars few, and the cleaner ones not much crushed, but the " dirty " ones passing out into " flaser ; " with shape and characters gone. The ground-mass is " damascened " with muscovite amongst quartz and water-clear feldspar.

- [E. 2481.] 4 to 6 ft. quartz-porphyry dyke : cliff at Traie ny Uainague, Maughold. See Fig. 35, p. 128.

Micro. A crushed quartz-porphyry, evidently an elvan of the Dhoon set. The ground-mass is cryptocrystalline, with biotite in small flakes in parallel arrangement. Phenocrysts of quartz and felspar, as usual, crushed, strained and full of mica ; the biotite phenocrysts are all gone to chlorite ; iron-ores, sphene, a little apatite, and a few garnets present.

- [E. 2384.] 6 ft. dyke : cliff 200 yards s. of Cor Stack, Maughold Head.

A sheared grey rock, horny and felsitic, without any obvious porphyritic constituent ; a fine-grained microgranite of the Dhoon set.

Micro. The ground-mass is a minute biotite-bearing microgranite, with phenocrysts mainly of felspar loaded with muscovite and quartz ; epidote fairly abundant, in large grains ; chlorite after biotite ; sphene ; iron oxides. Parallel series of folia which traverse the rock are about '1 inch apart, and consist of granular quartz, epidote, zoisite, chlorite and leucoxene, with or without iron-oxides, but this is more altered to leucoxene in these bands than elsewhere.

- [E. 2382] and [E. 2385], from the interior and margin of a dyke, 12 ft. to 15 ft. thick, at *Gob ny Skey*, Maughold Head.

This dyke is somewhat similar to [2384] ; the interior is more acid than the margin.

From the same set of elvans on the opposite or south-western side of the granite outcrop, the following example from a deep level of the Laxey mine deserves notice on account of its unweathered condition.

- [E. 2499.] 20 ft. dyke : 255 fathom level of Laxey mine, 490 yds. n. of Dumbell's shaft (see p. 521).

Micro. The structure of the ground-mass lies between minute microgranulitic and cryptocrystalline, with quartz, felspar and muscovite ; it is crushed and foliated. The chief phenocrysts are quartz with ground-mass inclusions and edges on which the ground-mass intrudes. Nests of muscovite in the ground-mass probably represent the relics of vanished felspars.

Other slides of the elvans at greater distances s. w. from the granite include the following :--

- [E. 2478.] 6 ft. sheared dyke : at 700 ft. contour on tram-line to Snaefell.

Micro. Much crushed, with abundant development of muscovite ; biotite all converted to chlorite ; sphene, epidote, and a few zircons present.

- [E. 2477.] 6 ft. "greenish quartz-porphyry" dyke : north feeder of Glen Roy, under Close Moor.

This has not got the usual micaceous felspars, and differs somewhat from the Dhoon set.

The Foxdale Granite and its Elvans.

Like the Dhoon granite, the Foxdale Granite forms, as it were, the node of a string of dykes extending with the strike of the country rock in both directions from the neighbourhood of the intrusion (see Fig. 29, p. 84). Its general field-relations and characteristics have already been described ; as also those of its elvans, which are usually distinguished by the presence of small hexagonal crystals of white mica ; and the petrology only remains to be discussed.

For the main mass of the granite, the following slide of an unweathered specimen from one of the Foxdale shafts may be taken as representative.

[E. 2791.] Granite : bottom of *Bawden's Shaft*, Foxdale Mines.

A moderately coarse-textured grey muscovite-granite.

Micro. The oldest minerals appear to be cores of felspar, usually striped and very much corroded so that mere skeletons remain. These are filled in and filled out by new felspar growth, also usually striped, giving rise to fairly angular and well-defined crystals. A few singly twinned orthoclase crystals are present, without such good boundaries. Muscovite appears to be the next mineral ; it also has irregular boundaries and does not contain many inclusions. Quartz is the next, and of this there is a considerable quantity, quite clear, and free from inclusions of other minerals. It and both felspars in small crystals are enclosed in large patches of microcline. A little quartz-mosaic is present. There are no signs of movement, and none of the minerals are crushed, bent, or broken, nor is there any undulose extinction.

Another slide [E. 2890] from the granite at the surface showed no microcline and very little orthoclase, the predominant felspar being well-formed plagioclase, probably oligoclase. In a slide described by Mr. Harker, brown mica was also present, in part in parallel intergrowth with the white, both micas exhibiting pleochroic halos surrounding minute zircon crystals ; and occasional grains of garnet were also observed.¹

The concealed granite reached by the shaft of Cornelly Mine (see p. 517), though exhibiting a general resemblance to the Foxdale Granite, is by no means identical with it, as the following description will show. The difference between them, however, is no greater than might occur between different parts of one and the same intrusion.

[E. 2893.] Granite : from spoil-heap of Cornelly Mine, 1½ miles N.E. of Foxdale.

Micro. In this rock the structure is hypidiomorphic, granular, with the crystalline outlines of the felspar less marked than usual. Plagioclase is abundant, and it often shows microperthite intergrowths which are sometimes twinned, and also micro-pegmatite. The bulk of the 'orthoclase' is *moiré* or microcline. Both biotite and muscovite are present, the former more or less replaced by chlorite, and the quartz is in large grains. The order of consolidation is not at all apparent. The rock is a *two-mica* granite, which differs from that of Foxdale in the presence of biotite and in the abundance of microcline, microperthite, and micropegmatite.

Of the Foxdale group of elvans the best-known and most accessible is the broad dyke exposed in the quarries close to the railway station at Crosby (p. 168), and this may be taken as the type for the set. Its petrographical characters have been previously described by Mr. B. Hobson,² and the rock has been analysed by Messrs. Dickson and Holland, with results quoted in Appendix II., p. 575. Large garnets may occasionally be observed in the small strings of vein-quartz at the margin of this dyke.

[E. 1983.] Crosby dyke (20 to 30 ft. wide), 4 ft. within its western margin : upper quarry, Crosby.

Macro. Light grey fine-grained rock containing hexagonal plates of a nearly white biaxial mica. One end of the specimen shows marked signs of shearing and the plates of mica have been distorted.

Micro. Occasional porphyritic crystals of orthoclase, plagioclase, and muscovite generally in fibrous aggregates, and quartz in aggregates ; the extinctions of these are undulose and some

¹ "Naturalist" for 1894, p. 68.

² In the paper to which references are given on p. 300, Mr. Hobson applied the term "quartz-keratophyre" to the rock.

are bent ; most are crushed and some separated. The ground-mass is granulitic on a small scale, quartz and orthoclase being present in about equal proportions, while striped felspar is absent. The muscovite is in small flakes between the grains of the other constituents. There is no linear arrangement, but the smallest grains show undulose extinction. There is no tailing off of the phenocrysts. A few nearly colourless garnets are present, like those sometimes seen in the Foxdale Granite. A muscovite-granite, crushed.

The crushing noted in the above slide is very generally observable among the dykes of this set ; and as in the Dhoon elvans, shows much local variation in severity. The next two slides show the more advanced stages in the process.

[E. 2796.] Elvan : small quarry on *Windy Common* (N. of m), S. of Foxdale Granite.

Micro. Phenocrysts of plagioclase, orthoclase, muscovite and quartz, the last strained, broken and granulated ; the two first tailed into mosaic, often arranged obliquely to the foliation in their crystallographic axes, but in form phacoidal with the foliation. The ground-mass is a foliated granulite, and doubtless represents a fairly marked stage in the crushing, as it consists of a felted aggregate of interlocking grains of quartz and unstriped felspar with muscovite interlacing amongst it ; little or no chlorite. A porphyritic foliated granite, probably once a micro-granite.

[E. 2083.] Sheared elvan : S. end of *Beal-feayn-ny-Geay*, W. side of Cronkny-Arrey Lhaa.

Micro. A sericite-schist with surviving knots of quartz, whose edges are crushed down to quartz-mosaic and muscovite, the latter penetrating the solid quartz of the knots. The rest of the slide is a minute quartz (? + felspar) mosaic filled in with sericite and chlorite, and with some folia made entirely of sericite. A few small garnets are present.

Among other slides examined of which the rocks probably belong to the Foxdale set of elvans were the following :—

[E. 2795.] 1 to 2 ft. vein : West branch of *Glion Darragh*, W. of farm ; near Cornelly mine (somewhat crushed).

[E. 2904.] White trap : Foxdale river, below Ballamoore, N. of Foxdale. (A quartz-mosaic schist with augen : contains a peculiar chlorite, or chloritoid : a crushed elvan having affinities with Dhoon set.)

[E. 2797.] 8 ft. elvan, sheared ; S. entrance to South Barrule Slate Quarries. (Well-foliated, and with no igneous structure left.)

[E. 2000.] Elvan : base of cliff at Raclay, E. side of Fleshwick. (Porphyritic constituents fresher than in Crosby dyke, and no sign of crushing.)

Acid Dykes of Doubtful Relationship.

Besides the recognisable Dhoon and the Foxdale elvans, other more or less acid dyke-rocks were discovered during the survey in various places, but principally, and indeed almost exclusively, on the N.W. side of the central axis, which could not be definitely assigned to either set and may in certain cases represent an independent and perhaps older type of intrusion. As these rocks were close-grained originally and have since been much disturbed and altered, and as, for the most part, they are seen only in limited exposures, the main evidence for their igneous

acter has been obtained from their examination under the microscope.

Lhergydho Trap.

One of the largest and best-marked of these intrusions occurs at the foot of the hills at Lhergydho, 2 miles E.N.E. of Peel, and is quarried for road-metal (see p. 156). The following is a slide of this rock :—

[33.] Dyke-rock : N. quarry at Lhergydho.

Micro. The porphyritic ingredients are mainly orthoclase in small crystals, often associated with plagioclase in groups of dozens of crystals and some fibrous sericite. No porphyritic quartz appears to view in association with these or alone. The matrix is very distinctive, though fine-grained. There are prisms (the length of which is twice or thrice their breadth) of orthoclase and plagioclase set in interstitial quartz : abundant and minute sericite flakes occur in and amongst them, and also in small associated masses of chlorite : carbonates are plentiful, but with nothing to show their origin. The rock is linked with the other elvans, but the ground-mass is somewhat distinct in having the visible and perfect prisms instead of grains.

Similar features are seen in another slide [E. 2916] from the same rock.

A porphyritic micro-granite or keratophyre, or acid andesite having affinities with the Ivernites.

The above rock lies outside the belt in which the Dhoon and Foxdale dykes occur, and so far as the field evidence alone is concerned, it cannot be connected with any other group of intrusions, though one or two satisfactory exposures in the country to the westward, mentioned in p. IV., may possibly represent the same rock in a more decomposed condition.

Still farther westward and north-westward, around the head-waters of the Glass and Sulby rivers and extending thence north-westward to the east coast south of Ramsey, exposures of much-crushed pale rock are met at intervals, which when submitted to microscopic examination show an affinity to the Lhergydho exposure. Their field-positions however do not suggest a relationship with the Foxdale elvans, and their difference from the normal type might perhaps be accounted for by the increased distance from the granite. The following is an example of these rocks :—

[396.] Pale dyke (?) ; gutter at Park Mooar at bench-mark 680'·3", near Ramsey.

A cream-coloured crushed rock with felspar-crystal eyes surrounded by pale chlorite ; occasional broader ferromagnesian bands.

Micro. This seems to belong to the Lhergydho set in its porphyritic crystals, but in its matrix it is more obscure ; still, the general character is in favour of this idea ; it possesses somewhat more quartz, but not definitely in phenocrysts.

Other slides of similar character are :—

[395.] Pale dyke (?) ; Glen Crammag stream, 650 yds. N. of road from Snaefell to Kirk Michael (see p. 139).

[479.] Large pale dyke or boss ; S. flank of North Barrule above Park Llewellyn (contains an exceptional amount of zoisite and epidote).

[506.] 6 ft. pale trap with dark needles ; tram-line at S. side of Glen Gawne, Garwick.

The last-mentioned is noteworthy as being the only known occurrence of this type so far to the eastward of the structural axis of the Island. The needles of the rock are composed of chlorite.

Altered Elvans.

The remarkable alteration of the greenstone dykes where they traverse the belt of altered slates has already been described, and we have now to deal with a similar, though less marked, alteration of the elvan dykes under the same circumstances. While the dykes which are thus altered are always in a crushed condition, the preceding descriptions will have shown that there are crushed elvans in other parts of the Island which are not markedly altered.

That the elvans should have been anywhere altered implies that at least some part of the alteration has been of later date than the intrusion of the granites, since these elvans appear to have represented the latest phase of intrusion (see p. 166). But as the slates had probably undergone a schistose alteration before the granitic invasion (p. 106), we are led to the conclusion that the metamorphic action was spread over a period of long duration, and probably came into play intermittently during this period.

The most striking example of an altered elvan is that occurring on Greeba Mountain, a little to the eastward of the summit, as described in Chap. IV, p. 158. The following is a slide from this locality. Red garnets were abundant in some parts of the rock, but apparently were absent from this slide.

[E. 2798.] Sheared elvan ; near summit of Greeba Mountain, N.E. of the cairn.

Micro. A characteristic Foxdale elvan, but without phenocrysts ; quartz-felspar mosaic, lineating but not foliating the rock, and abundance of muscovite. The striking feature is *chloritoid* crystals, which enclose the quartz-felspar matrix inside them, so that the inside of the crystals is a mere aggregate, the outside being much more pure. The muscovite is sometimes gathered into fan-shaped groups. Altered elvan.

The more common kind of alteration of these elvans is shown in the next slide, which is from an intrusion exposed in the stream draining the N. slope of Snaefell, not far from the actinolite traps [2389] and [2407] described at p. 309.

[E. 2398.] Boss or dyke : stream S.E. of Block Eary, 140 yards N. of mountain-fence.

A white granular rock with bands of black mica ; sheared microgranite.

Micro. A fine granulitic quartz-felspar matrix of Foxdale-elvan type ; well-foliated, with only rounded porphyritic quartz. The foliation is mostly due to muscovite or sericite in sheets, in which occur flakes and crystals of biotite, the former in the foliation, the latter frequently extending across it. Associated with the biotite are occasional patches of leucoxene.

Among other examples of similar character in the Survey Collection are the two following slides, in which, however, zoisite and garnet are seen, as well as biotite.

[E. 2800.] 20 to 30 ft. boss or dyke : bed of River Glass, 450 yards N. of Baldwin Chapel.

[E. 2801.] 2 ft. dyke : same locality, 500 yards N. of Baldwin Chapel.

ther of the altered acid dykes approximate more nearly to the Lhergy-type, of which the following may serve as an example.

[2393.] 8 ft. dyke : Injehreck stream, due w. of hotel.

Pale microgranite or felsite with ferromagnesian mineral and brownish spots on the cut surface.

Micro. Characteristic Lhergydho type, with few porphyritic crystals. Matrix characteristic except porphyritic feldspars which are sometimes grouped. The only other porphyritic ingredients are biotites, sometimes changed into pale brown chlorite, polarizing in weak colours. These have the appearance of development subsequently to consolidation and they may be *metamorphic*.

Port-e-Myllin Dykes.

ie curious group of intersecting dykes at Port-e-Myllin, described and treated at p. 124, Fig. 34, deserve notice before we conclude this account of elvans. The oldest rock (lettered F. in the figure), which is cut by the two greenstones, is probably a much-crushed intrusion approximating to the Lhergydho type, as the field-evidence suggests its connection with the dykes at Park Moar, $1\frac{1}{2}$ mile farther west, which is believed to belong to the same set (see previous description, slide [2396]). While the intersection of greenstone dykes by later intrusions of microgranite, as already shown (slides 128-30), is a comparatively common phenomenon in the Island, this is the only known instance of the intersection of one of the acid group by greenstone. Moreover, the smaller of the intersecting greenstones is much redder, and therefore probably one of those early basic intrusions which elsewhere seen to be cut by the Dhoon and Foxdale elvans. The rock which it is intrusive must, of course, be still older ; so that the antiquity of the more acid rock would seem to be considerably greater than that of the above-mentioned granites. If its correlation with the Lhergydho set is accepted, this set would thus appear to constitute the most ancient intrusive rocks known in the Island. The earlier greenstone (lettered Bg) is itself reduced to a calc-chlorite schist, while the later greenstone (lettered Bd) which cuts it, is comparatively unaffected by movement and can be recognized as a porphyritic diabase. The slides of the three sets are as follows :—

[2920.] The pale rock ; F. of Fig. 34 : Port-e-Myllin.

A grey medium-grained rock, much sheared.

Micro. It bears some resemblance to [2918] (an intrusion on the N. side of Port Lewaigue, $\frac{1}{2}$ mile to north-westward, which contained *augen* made up of plagioclase, quartz, and micropegmatite, associated with abundant apatite, chlorite, and calcite), but is further sheared. The *flaser* contain quartz in rather larger masses than [2918], but the feldspar and micropegmatite are less easily recognizable, although undoubtedly present in some cases and strongly suspected in others. Limonite, sericite, chlorite, and abundance of carbonates are the other minerals in the ground-mass, and to some extent in the *flaser*. Sheared dacite (or elvan ?)

[2921.] Sheared greenstone cutting [2920] ; Bg. of Fig. 34. Port-e-Myllin.

Much sheared greenish-buff rock, with knots of carbonates.

Micro. Very like [2919]—(a schistose dyke cutting [2918] on the N. side of Port Lewaigue, see p. 123, which showed *flaser* of carbonates, granular quartz and feldspar, with chlorite around them, and a few flakes of muscovite (?) lying between and shut in the *flaser*)—and the muscovites (?) are similarly situated, but are better developed, while the perfect terminations and

rather low interference colours sometimes raise a doubt as to whether they are all muscovite: it tends to occur best at the junction of the carbonate *flaser* with the chlorite ground-mass, but occasionally in the body of both. Calc-chlorite schist.

[E. 2922.] Greenstone cutting [2920] and [2921]; Bd. of Fig. 34: Port-e-Myllin.

A buff fine-grained rock, showing small needle-like phenocrysts.

Micro.—There can be little doubt that the phenocrysts have been felspar, but they are now converted into groups of fair-sized grains of muscovite. The ground-mass is a fine-grained tangle of small felspars with elongated iron-ores, with muscovite in places. Altered porphyritic basalt.

Quartz Veins.

The quartz veins associated with the Dhoon and Foxdale granites deserve notice here, as the most conspicuous vein at Foxdale has been considered by Mr. Harker to possess the characteristics of *greisen*¹, and therefore to represent the residual material from the cooling of the granitic magma. As already described, these veins are a marked feature throughout the Manx Slates, occurring everywhere, either in narrow strings frequently crumpled and torn, or in broader lenticular "eyes." At the margin of the granite-bosses they are especially well-developed, the majority gashing the granite, as well as the country-rock, in an approximately N.—S. direction. They frequently contain small quantities of other minerals as inclusions, such as (roughly in the order of abundance) yellow mica, chlorite, tourmaline (see p. 143), felspar, ilmenite, etc. Their mode of occurrence is in many respects comparable to that of the elvans; but, so far as we could find, they do not anywhere present indications of a gradual passage into either granite or elvan, though such might have been expected if they were truly *greisen*. On the contrary, their boundaries in these rocks are always sharp and distinct. On the whole, that they have been formed in crevices by infiltration and segregation under the influence of thermal waters appears more probable than that they have been injected along continuous fissures like the dykes. They are evidently of widely different ages, and may have been produced under diverse conditions.

The Oatland (Santon) Complex.

The small boss of granite with its peculiarly associated rim of dark basic rock which crops out at Oatland in the parish of Santon, as described in Chap. IV., p. 185, is deserving of especial attention from the petrographical standpoint, but unfortunately is not well-exposed. The more acid rock occupying the central part of the intrusion² is clearly of later consolidation than the basic rock which it penetrates in a series of veins, though

¹ Quart. Journ. Geol. Soc., li., p. 143.

² This rock was first described by Mr. B. Hobson: *op. cit.*

the actual junction of the masses could not be seen at the time of our examination. Angular and subangular fragments of the dark rock are included in the granite in increasing numbers towards its margin, until, as some of the boulders around the outcrop show, the inclusions bulk more largely than the acid matrix; and finally the granite is reduced to a few narrow veins traversing the dark rock. In certain places, however, the appearances suggest that there may locally be a passage or blending of the two rocks, possibly the result of refusion of the older, as augite crystals occur isolated in the grey granite. No conclusion has been reached as to the length of the interval between the intrusions; nor as to whether the complex has been the result of the differentiation of a single magma of which the basic margin was first cooled, or of two separate intrusions of different composition along the same conduit.

The mass as a whole is very little sheared, except along a plane near its centre, where a small quarry recently opened revealed a certain amount of crushing such as might accompany a fault.

As the following petrographical notes will show, the basic rock has close affinities with some of the previously described 'greenstone' dykes of the Island, while the granite is not far removed from some of the diorites. The boss may, indeed, be regarded as the largest of the knobs or nodes on the clustered dykes which run along the south-eastern side of the massif parallel to the central axis.

[E. 2907.] More acid portion of granite: quarry near Oatland, Santon.

A grey rock showing felspar, quartz and chlorite on the broken surface.

Micro. The felspar is much altered and crowded with muscovite, so that it is hardly possible to recognize the twinning; the plagioclase is the more perfect, the pinacoidal faces being well marked; the orthoclase is recognizable generally in much less regular grains, with only traces of crystal faces. The chlorite has the habit of altered biotite and is full of pleochroic halos; a little hornblende and epidote are associated with it. The quartz is generally clear and in large interstitial grains; here and there it is in small grains, but the general habit is quite different from the Dhoon granite and more like the Foxdale granite in this respect. There are a few epidote veins. A granite.

In another slide [2908] where the rock is slightly more basic, similar features are observed, but epidote is more abundant. There are no signs of crushing in either slide.

[E. 2910.] Specimen from near western margin of Oatland granite.

Granitic ground-mass with very abundant crystalline masses of hornblende up to $\frac{1}{4}$ inch across.

Micro. This rock has a ground-mass quite like that of the rest of the Oatland granite, made up of much clouded felspar embedded in quartz. Embedded in this is green hornblende which appears to be original, and a considerable quantity of another mineral which has high refractive index, low double refraction, slight pleochroism, and a muddy brown colour, and in certain sections splits up with a fine ragged cleavage like a mica; the extinction appears to be straight. Embedded in

this rock are large rounded grains of uralitized augite of a pale green colour and very slight pleochroism. They are always bordered with a more or less complete ring of green hornblende. These augites probably compare with those in one set of greenstones.

Hornblende granitite containing augites.

Another slide [2911] from a similar rock on the north-eastern side of the granitite showed the same features, intensified.

[E. 2909.] Knobs of basic rock in normal Oatland granitite.

These are large black knobs containing large hornblendes in a felspathic matrix, loaded with hornblende at the margin.

Micro. The "normal" rock furthest from the junction shows, first of all, chlorite after biotite, mingled with green idiomorphic hornblende, and the usual felspar and quartz of the granitite. Then a brownish-green hornblende begins to come in; then, one or two large patches of mingled green and brown hornblende associated round a fibrous mass of actinolite (?) (the centre is probably uralitized augite). The felspars are very much clouded, and increasingly so towards the margin, where only small traces of biotite are left.

Across the boundary into the basic knot everything becomes allotriomorphic, and large masses of felspar grains occur, with hornblende masses submerged in them. The hornblende, as before, is green and brown mingled, and the association is suggestive of the hornblende outside, as if it had been derived from here. Quartz occurs only very occasionally.

The chlorite in this slide is beginning to take on the characters of the unidentified mineral in [2910].

[E. 2912.] Basic part of Oatland intrusion.

A dark-green hornblendic rock showing large faces of hornblende.

Micro. The chief mineral here is augite more or less changed into uralite, but often unchanged. Interpenetrating it in ophitic fashion is much brown hornblende in tiny particles; round the edges and sometimes enclosing one or several augite grains, but in optical continuity with them, is much brown hornblende. A third mineral in cloudy highly refracting irregular grains is abundantly present; it may possibly be one of the epidotes, but has not been definitely identified. Some ilmenite or magnetite is present.

Ballabunt Dyke.

About 2½ miles N.N.E. of the Oatland intrusion there is a small boss or dyke of igneous rock of abnormal composition which has some features in common with part of the Oatland mass, and is therefore described here. The details respecting the exposure have been given in Chap. IV., p. 170. The following is the petrographical account of the rock:—

E. 2831.] Porphyritic mass: quarry on w. side of road striking s. from Ballapaddag, near Ballabunt.

Macro. Large dark-green porphyritic crystals, sometimes ½ inch in length, in a nearly white fine-grained matrix.

Micro. This rock has decided affinities with the medium basic rock of Oatland. There are large masses of uralitized augite, pale green and slightly pleochroic, often with actinolitic tangles in their interior, while the outer border is frequently changed into dark green hornblende in exact optical continuity. Small interior patches of fibrous colourless amphibole (? tremolite) occur occasionally inside these masses. A little compact green (original) hornblende is present, and a consider-

able quantity of biotite now entirely altered into chlorite, and a few grains or skeletons of ilmenite, more or less changed to leucoxene. The feldspars are idiomorphic, just like those of Oatland, and changed to mica masses; even the genus is indeterminable: they project into quartz with exactly the Oatland habit. Augitic granitite.

Another slide from the same quarry [E. 1982] is practically identical with the above, but apatite is present, and occasionally microcline takes the place of interstitial quartz.

Rocks of Doubtful Origin.

In the preceding pages reference has been made to the occurrence among the Manx Slates of bands of rock regarding the original character of which neither the field-evidence nor the microscope gave definite results. From the prevalence of dyke-rocks in which the igneous structure is barely recognisable, it is probable that most of these doubtful rocks are also of igneous origin. Numerous slides of these rocks were prepared and examined, but as they rarely present any salient features, being usually in the condition of fine-grained schists, it is needless to enter into details respecting them. The only example which will be given is the following, which presents somewhat unusual characters.

[E. 2394.] Pale hard bed; ? dyke-rock. Second side-glen w. of Block Eary, Ballaskella.

Micro. Compact pale rock rich in quartz: some pyrites and a white cleavable mineral in small grains. In its present state the rock is undoubtedly clastic and made almost solely of quartz, with bands parallel to the quartz-veins probably made of a carbonate, which does not, however, appear to be calcite, and, as it is generally associated with iron ore, may possibly be leucoxene. I cannot make out any feldspar at all in the rock, nor can I name the cleaved mineral. The structure, however, must, I think, have been produced *in situ*, as the grains fit one another exactly or else are separated by a minute mosaic whose grains similarly fit together. The grains in the quartz-veins similarly accommodate one another. Average size of main grains '005 in., of mosaic grains '001 in.

A minute *quartz-breccia*.

Supposed Tuff.

The curious isolated patch of andesitic breccia outcropping among the Manx Slates near Dalby, as described in Chap. IV., p. 163, presents the following characteristics:—

[E. 2118.] Andesitic breccia or tuff (?): field-road, 100 yards E. of high road at Ballaquane, near Dalby.

Micro. An andesite with needles of plagioclase in what has been glass but is now turbid and isotropic: holes and veins filled with quartz, chlorite, and siderite: no trace of "bombs," and the rock has every appearance of having been brecciated *in situ*.

[E. 2985] and [E. 2986]. Same rock as last : small quarry in field, 50 yards s.w. of last.

Micro. The ground-mass is very obscure, but contains felspar crystals : the fragments are mainly of an andesitic or felsitic nature—probably both, angular and set in a much finer-grained matrix without any sign of stratification. Each slide contains lapilli—probably once glass—full of spherical amygdaloids. Andesitic tuff.

A rock shown by the microscope to have some affinity to the above, but supposed, when the specimens were collected, to be a dyke, was observed in two places in the s.w. corner of the Island, but unfortunately in both cases in limited and obscure exposures. The slides from these places are :—

[E. 2105.] Sheared dyke (?) : N. side of road at most easterly house of Cregneish.

Micro. A breccia made of a trachytic kind of rock solely. The fragments are generally rounded, and consist of a rock made up of felspar prisms (laths) embedded in interstitial quartz (with (?) felspar). Occasionally a mica pseudomorph is found in them. What ground-mass there is seems to be chlorite and quartz grains. It must, I think, be a rock of trachytic character broken up *in situ*.

[E. 2109.] Grit or dyke (?) : Hillside 40 yards N. of road, 500 yards E.N.E. of Chasms House.

Micro. Related to [2105], and either an igneous rock brecciated *in situ* or a volcanic tuff : fragments rather more rounded than in [2105], as if waterworn.

II. Carboniferous Volcanic Series.

As the petrography of the Carboniferous Volcanic Rocks has been treated of in detail by Mr. B. Hobson in the paper already cited, and as the present investigation has confirmed his results, it will be sufficient here to give one or two illustrative examples of the more conspicuous of these rocks, with a few additional notes on points not dealt with by Mr. Hobson. The complicated structure and general relations of the series have been discussed in an earlier chapter (p. 226).

The following is a general description of the porphyritic basaltic rocks forming the Stack of Scarlet and the broken dyke-like ridges (probably originally lava-flows : see p. 248 and Figs. 68, 70) between the Stack and Cromwell's Walk, based on the slides [1802], [1803], [1804], [1805], [1806], and [1807] of the Survey Collection. The rocks are of a dark greenish-grey colour, with porphyritic plagioclase crystals up to $\frac{1}{4}$ inch in length, and are often amygdaloidal, especially at the margin.

Under the microscope the structure is usually porphyritic, with large idiomorphic plagioclase crystals in a ground-mass of small needle-like feldspars embedded optically in chlorite, calcite and abundant iron-ores. In one of the slides [1804], however, the large feldspars are absent. In another [1803] chlorite replacements after olivine or hypersthene are recognisable. The amygdules are filled with carbonates, chlorite, quartz, and a zeolite, the last generally radiating.

Mr. Hobson applied the term "augite-porphyrite" to these rocks, but as they all belong to the basic rather than to the intermediate group, and as augite, though no doubt originally present, can no longer be recognised in them, it seems preferable to style them "porphyritic diabases," using "diabase" in the ordinary sense of an altered dolerite. In the general stratigraphical descriptions given in Chapter V., the common term "basalt" has been applied to them in a broad general way.

Mr. Hobson has described a dyke-rock ("the melaphyre dyke") occurring at the northern margin of the Volcanic Series at Scarlet, which differs from the rocks above described only in the presence of recognisable crystals of augite and pseudomorphs after olivine. There is no doubt that this dyke is connected with the Volcanic Series, and is therefore of Carboniferous age. Another dyke which appears to be of this age, also described by Mr. Hobson, occurs on Langness (see p. 195), rising through the slates into the overlying Carboniferous Conglomerate. Its characters are as follows:—

[E. 1807.] Dyke cutting slates and conglomerate: N. end of The Arches, Langness.

Micro. Amygdaloidal diabase, much decomposed; minerals entirely gone, but shapes of feldspars quite unmistakable. Amygdules consist of fine chlorite with idiomorphic dolomite crystals embedded, and the outside of the cavities appear to have been of interstitial matter which was abundant in the rock.

Another dyke which may belong to the Carboniferous group occurs on the outer margin of the shore south of Castletown harbour, as described on p. 203. The following is a slide of this rock:—

[E. 1954.] Dyke or boss in Carboniferous Limestone: *Creg Kermode*, Castletown Bay. Compact grey rock with a brown crust.

Micro. Much decomposed to calcite and chlorite; resembles the Carboniferous set. Feldspar needles in ground-mass amongst chlorite and interstitial matter which increases near the amygdules, and eventually forms a ring round them sometimes thicker than the diameter of the amygdules themselves. The latter are almost entirely calcite with a little chlorite. The interstitial matter has been quite a tachylyte filled with rods of iron ore.

In a slide [E. 1953] from another part of the mass, where the rock was of darker colour and more definitely crystalline, it more nearly resembled a fairly coarse ophitic olivine-dolerite of the supposed Tertiary group, much decomposed.

The reef Lheeah-rio, which is uncovered at low water in Castletown Bay about $\frac{1}{4}$ mile S.E. of *Creg Kermode*, seems for the reasons given on p. 247 to be more closely associated with the Carboniferous Volcanic Series than with the later set of olivine-dolerite dykes. The petrographical evidence tends to link it with these later dykes; but as the two slides from *Creg Kermode* show that different parts of the same mass may suggest association in one case with the Carboniferous Series and in another with the later set, this evidence can scarcely be regarded as decisive. The following is the description referred to:—

[E. 1955.] Basaltic rock: from near the centre of Lheeah-rio, Castletown Bay.

A dark-green medium-grained massive rock.

Micro. Ophitic olivine-dolerite without phenocrysts and with hornblende replacements of olivine; the augite is pale-brown—not so deep as in the Strandhall dyke [1808] (see p. 328). A zeolite which appears to be analcime occurs between the feldspar laths. The balance of evidence is in favour of associating this slide with the olivine-dolerite set rather than with the Scarlet set.

In a few places outside the limits of the Carboniferous tracts, basic intrusive rocks occur, which so far as their microscopic structure is concerned might be classed with the Carboniferous set; but in most cases the field-evidence affords no ground for separating them from the pre-Carboniferous greenstones along with which they are found. The diverse character of the greenstones has already been discussed, and it must be acknowledged that some are of later date than others; but until better evidence is forthcoming to discriminate their age, it is perhaps safest to regard all the dykes of the Manx Slate area as pre-Carboniferous, except the (Tertiary?) olivine-dolerites. Among the dykes which have been thought to show petrological affinity to the Carboniferous set were two on the west coast near Peel, and another in the interior two miles west of Peel (see p. 156); and these are all close to the margin of the Peel Sandstone, but do not intrude upon that formation, and are therefore scarcely likely to be of later date. Further details will be found in Chap. IV. as to the localities where greenstone dykes of the newer aspect occur.

Volcanic Ash and Ashy Limestone.

The structure and composition of the volcanic ash is sufficiently described in the passages quoted on pp. 228-33, from Sir A. Geikie's account of the series, the petrographical examination under the microscope having revealed no additional features.¹ In most of the slides no signs of crushing were visible. A specimen from one of the strips of chert enclosed in the ash at *Close ny Chollagh Point* (p. 236) was cut and examined [E. 2929]: it is seen to be rudely bedded and twisted, and exhibited no trace of clastic grains, and no organisms. An ashy limestone from the same locality [E. 2991] (see p. 237) proved to be made up of fragments of crinoids, corals, shells and other organisms, with indubitable lapilli of a basaltic rock, full of bubbles, and no clastic fragments of any other kind. A slide of calcareous ash [E. 2993] just below a small thrust-plane on the foreshore, n.w. of the Poolvash quarry (p. 235), showed the vesicles to be drawn out and twisted, and a certain amount of veining parallel to the twisting direction, rather suggesting that the rock had been crushed. Other slides of the disturbed rocks exhibited little or no indication of structural modification.

¹ See also Mr. B. Hobson's descriptions: *op. cit.*, pp. 442-3.

III. The Post-Carboniferous (Tertiary ?) Olivine-dolerite Dykes.

Cumming was the first to distinguish between these dykes (the newest 'solid' rocks of the Island) and the older intrusives. Beyond the fact that they are Post-Carboniferous there is no direct evidence for their age in the Island, but as they agree very closely in composition, mode of occurrence and general north-westerly direction of strike, with the basaltic dykes of Tertiary (Miocene) age in Ireland, Scotland, and the North of England, it is believed that they belong to the same period of eruptive activity. They are especially numerous in the Carboniferous rocks of the south of the Island, where they have been frequently studied; but our mapping has shown that they occur at irregular intervals throughout the slate-massif also. They tend to run in groups, which probably traverse the Island from side to side, though the individual dykes can rarely be traced for more than a short distance. They are well-exposed in the coast-sections, but more rarely in the interior owing to their rapid destruction by weathering. They appear to decrease in numbers with the altitude of the surface, and not a single example has been found at over 700 feet above O.D. (See list, p. 329.) If not simply due to weathering and consequent lack of exposures, their absence at greater altitudes may imply that the injection-pressure was insufficient to force them up through the higher ground of the Island.

The dykes vary in width from an inch or two to about 24 feet (excluding, as doubtfully of this age, the much larger masses of Creg Kernode and Lheeah-río previously discussed). The broader dykes traversing the Carboniferous Limestone have decolourized and slightly altered that rock for an inch or two along the contact, but their metamorphic effect is usually almost imperceptible. Except that they are sometimes slightly broken and shifted by small faults, these dykes have suffered no deformation; and their intrusion was evidently subsequent to the latest of the severe earth-movements affecting the Island.

The occasionally close association between these intrusions and the metalliferous lodes is a point of economic as well as scientific importance, but will be more conveniently discussed in a later chapter (p. 488). In view of this practical interest, a full list of the dykes is given at the end of the present chapter, to which the reader is referred for detailed information regarding them.

The petrographical characters of the olivine-dolerite dykes of the south of the Island have been carefully described by Mr. B. Hobson, and we have nothing to add to his detailed account of their structure. It will be sufficient to give for comparison a short abstract of the features of a typical slide from this area, and afterwards an account of two or three slides from other parts of the Island where these dykes had not previously been recognised.

[E. 1808.] 18 ft. dyke: beach at *Strandhall*, Bay ny Carrickey. Greenish-black massive rock.

Micro. Sub-ophitic; plagioclase laths; pale-brown augite quite fresh; large green hornblende patches which are almost certainly after olivine; glass-patches of considerable size.

- [E. 2001.] Dyke, crossing π branch of Colby stream, 150 yards above junction at Ballacannell, Arbory.

A dark olivine-basalt with large cleavage faces of augite, twinned feldspar and probably olivine: dark brown weathering.

Micro. Precisely similar to [1808]. An *ophitic* olivine-dolerite with violet brown slightly pleochroic augite embedding long clear plagioclase laths. The augite shows no decomposition. There are considerable masses of green alteration products, varying from almost colourless to yellow, brown-yellow, light, dark and turbid green. The yellower varieties occur in masses suggesting the shape of *olivine* crystals, and sometimes infill the feldspars. The very light occurs in spheroidal aggregates, also probably after olivine. The darker and turbid greens are strongly pleochroic with straight (so far as it can be determined in them) extinction. These have the other reactions of hornblende, and are somewhat fibrous in arrangement under a high power. Possibly this may be *pilite*. No trace of any interstitial matter, only here and there smaller feldspars amongst the serpentine. The pseudomorphs often occur in augite plates, another point in favour of their being after olivine. The augites are often reduced to thin plates between feldspars. A good deal of magnetite is present in large crystals.

- E. 2408.] Dyke: Narradale stream, 300 yards E. of *Grangee*, Sulby.

This rock is a porphyritic olivine-basalt. It contains long twinned laths of plagioclase feldspar, and grains of olivine which are absolutely fresh, set in a plexus of feldspar needles, which again are embedded in small grains of brown augite. The rock might well be a Tertiary dyke.

It is probably a prolongation or branch of this dyke which traverses the crush-conglomerate and also intersects one of the old 'greenstone' intrusions in the quarry at Kerroo Moor, 700 yards to the north-eastward. (See p. 134.)

The last two dykes to be described differ from the normal type of olivine-dolerites, and some doubt is felt as to their inclusion with this group. Indeed the last of the two [2498], as described on p. 152, has such a distinctive aspect in the field that it has not been included in the subjoined list of olivine-dolerites.

- [E. 1956] and [2818.] Basaltic dyke: 200 yards s.w. of *Slack Indigo*, Douglas Head. A black compact basalt.

Micro. A tholeiite with intersertal structure. A few clear sanidine-like crystals of plagioclase. A mesh-work of plagioclase laths, well preserved and bright and clear. The ground is much impregnated with carbonates and no glass can be found, though there is good reason to believe it once existed and is now devitrified. Decided grains of augite, a good deal altered to chlorite and calcite occur between the feldspars; they are colourless, with the usual reactions. Plenty of minute crystals and rods of magnetite. No decided olivine, but serpentine pseudomorphs after enstatite or olivine, probably the former. No certain analcime; occasional calcite amygdaloids, round which is generally a zone of elongated plagioclases. Basalt (tholeiite), probably Tertiary.

- [E. 2498.] 3 to 4 ft. porphyritic dyke: cliff at the Clytt, Clay Head (p. 152).

Micro. Large porphyritic feldspars, and probably olivines in much decomposed condition embedded in ophitic dolerite matrix, in which the minerals are much altered to chlorite, calcite, etc. This is likely to be a Tertiary dolerite.

LIST OF OUTCROPS OF THE POST-CARBONIFEROUS (TERTIARY?) OLIVINE-DOLERITE DYKES IN THE ISLE OF MAN.

NOTE.—Of these dykes, those of the south-western coast probably represent the prolongation of those of the south-eastern coast; and of the last-mentioned, certain dykes seen on the outer or eastern shore of Langness no doubt reappear on both sides of Castletown Bay, and again on the eastern side of Bay ny Carrickey, but as their individual identification is difficult or impossible, all the outcrops are recorded separately. Unless otherwise noted the dykes are intrusive into the Manx Slate Series. Place-names in italics are those not given on the one-inch Ordnance Map. The distances given below have been measured on the six-inch field-map.

	Locality.	Average Width of Dyke.	Average Direction of Strike.	Remarks.
NORTH-EASTERN DISTRICT.				
5	Cliff and shore S. of Maughold Head, W. side of <i>Dhrynane</i>	3ft.	N. 35° W.	"Umber Mine" dyke, see p. 126.
3	Cliff and shore S. of Maughold Head, 100 yds. S. of <i>Dhrynane</i>	4ft.	W. 15° N.	vein-stuff on S. side.
	Cliff and shore S. of Maughold Head, S. of Port Moor, 300 yds. S. of cottage	9ft.	W. 40° N.	hematitic vein-stuff on N.E. side.
5	Inland; head of glen adjoining Glen Auldyn at Belleigheragh	8ft. and branches	W. 35° N.	
	Inland; S. fork of above glen, 50 yds. S. of last -	?	?	scanty exposure near old lead workings.
4	do. Kerroo Moor, in stone quarry - -	1ft. to 2ft.	N. 15° W.	also in adjacent old mine, see p. 134.
	do. bed of stream in gully 300 yds. E.S.E. of Cronk Sumark	?	?	inadequate exposure; rock unusually fresh, see p. 328.
EASTERN AND CENTRAL DISTRICT.				
1	Cliff 1 mile S. of Laxey, opposite Ballabeg - -	6ft.	W. 15° S.	well exposed; see p. 151
	do. 1 mile S. of Clay Head, east of Ballakilly -	4ft.	N. 35° W.	
2	do. 1 mile S. of Douglas Head, 200 yds. S.W. of Black Indigo	5ft.	N. 40° W.	classification doubtful; see p. 328.
	do. 2 miles S.E. of Douglas Head at extremity of Little Ness	two, each about 3in.	N.W.	perhaps filers from larger dyke not exposed.
	do. 2 miles S.E. of Douglas Head, recess west side of Little Ness	two, each about 6in.	N. 20° W.	perhaps prolongation of last.
	Shore in middle of Port Soderick - - -	4in.	W. 30° N.	
17	Cliff 400 yds. S. of Port Soderick. - - -	1ft.	irregular, W. 15° N.	classification doubtful
	do. 150 yds. W. of <i>Purt Veg</i> , Santon - - -	2½ft. and filer 1½ft.	N. 30° W.	
	do. and cave 100 yds. E. of Port Greenaugh -	1ft.	irregular, W. 20° N.	with vein stuff.
	Shore 150 to 300 yds. W. of do. - - -	1ft. to 2ft.	W. to W. 10° S.	
	do. and cliff, 400 yds. W. of do. ; 100 yards W. of <i>Yraie ny Gill</i>	2ft.	N. 35° W.	
	Shore and cliff, about 40 yds. W. of last - -	3ft.	N. 35° W.	
	Shore 500 yds. east of Port Solderick, Santon	1ft. and filer.	W. 18° N.	
	do. and cliff, 320 yds. E. of do. - - -	½ft.	N. 40° W.	
12	Inland; at East Foxdale Mines, Eairy - - -	?	?	accompany fault stuff see p. 514
	do.; S.W. of South Barrule in feeder of Silverburn, 350 yds. above Castletown reservoir	1½ft.	N. 40° W.	much decomposed; at altitude of about 700ft.
	Inland; S.W. of South Barrule; in the west arm of Silverburn, 30 yds. below highroad at Garey Moor	?	N. 25° W.	much decomposed; worked in adit; at altitude of about 700ft.
16	Inland; stream 250 yds. W. of Ballacannell, near head of Colby River	abt. 10ft.	W. 40° N.	unusually fresh; altitude about 450ft.
	Inland; Colby River, 20 yds. below <i>Colby Corn Mill</i>	8ft. and filer 1ft.	W. 10° N.	
	Inland; <i>Bellabey Glen</i> , at parish boundary. 500 yds. W. of Colby	?	W. 10° S.	at trial adit
	Inland; Ballacorkish Lead Mines	?	?	see p. 532 } ? all one dyke.

Number of Six-inch Sheet.	Locality.	Average Width of Dyke.	Average Direction of Strike.	Remarks.
SOUTH-WESTERN COAST.				
Sheet 12	Shore and cliff, 900yds. N. of Dalby Point - -	3ft.	N. 30° W.	also two small dykes at north of it
"	do. North side of do. - -	2½ft.	W. 20° N.	
"	do. South " " " at Bay ny Oaig	2½ft.	W. 30° N.	
"	Shore and cliff, under Cronk ny Arrey Lhas, 350yds. N. of Stroin Vulgh	3ft.	W. 15° N.	
"	Shore and cliff, under Cronk ny Arrey Lhas, 70yds. S. of Stroin Vulgh	6ft.	W. 30° N.	cuts a mic dyke.
Sheet 16	Shore and cliff, under Gob ny Beinn, 300yds. S. of The Stacks	1ft.	W. 35° N.	cuts a mic dyke; 7yds. S. of the other; another poorly exp.
"	Shore and cliff, ½ mile N. of Fleshwick, S. side of Gub ny Trale Ruy	4ft.	N. 35° W.	
"	Shore and cliff, N. side of Fleshwick, 250yds. S. of Raelay	1ft.	N. 40° W.	probably associated with old mining adjacent.
Sheet 15	Shore and cliff, 800yds. W. of Fleshwick; W. side of <i>Lhaob ny Charra</i>	8ft. branching	N. 30° W.	see p. 180.
"	Shore and cliff, North Bradda Mine, accompanying lode	1ft. to 2ft.	N.	
"	Shore, North Bradda Mine, striking off from lode	3ft.	W. 25° N.	see p. 180; p. 181 also inland.
SOUTH-EASTERN COAST. ¹				
Sheet 16	Shore 150yds. N. of Loch Skillieore; in Carb. Limestone	1ft., 3ft., 1ft., 8ft., etc.	N. 40° W.	interlacing of several dykes
"	Shore, Derby Haven, E. of <i>Breakwater</i> , 150yds. N.E. of lighthouse. in Carb. Conglomerate and Limestone	2ft.	N.W.	
"	Shore, Derby Haven, E. of <i>Breakwater</i> , 120yds. N.E. of lighthouse, in Carb. Conglomerate and Limestone	7ft.	N.W.	
"	Shore, Derby Haven, 150yds. S. of lighthouse, in Carb. Conglomerate and Limestone	6 to 9ft.	W. 35° N.	accompanying
"	Shore, Derby Haven, at N. end of Causeway to St. Michael's Island	1½ft.	W. 10° N.	
"	Shore, Derby Haven, 55yds. N. of Causeway to St. Michael's Island	2ft.	N.W.	
"	Shore, Derby Haven, at S. side of gully separating St. Michael's Island from Langness	1ft.	N.W.	
"	Shore, Langness, <i>Martha Gullet</i> - - -	1½ft.	W. 20° N.	
"	do. do. 50yds. S. of do. - - -	3 to 7ft.	W. 30° N.	interlacing of
"	do. do. 75 " N. of <i>The Goayr</i> - - -	irregular	W. 25° N.	interlacing of
"	do. do. <i>Spirs Gullet</i> - - -	branches 1ft.	N.W.	
Sheet 19	Shore, Langness, at <i>Dreawick Point</i> - - -	2ft.	N. 30° W.	
"	do. do. at Langness Point - - -	1½ft.	N. 20° E.	accompanying lode; see p. 181
"	do. E. side of Castletown Bay, 200yds. N.E. of <i>Port Bravag</i>	4ft.	N. 30° W.	probably associated with <i>Dreawick</i> lode; see p. 181
"	Shore, E. side of Castletown Bay, opposite copper mine	branches, ½ft. to 3ft.	N. 15° W.	branching; accompanying lode; see p. 181
"	Shore, E. side of Castletown Bay, 150yds. N. of copper mine	branches, 1ft. to 4ft.	N.W.	numerous in branches.
"	Shore, E. side of Castletown Bay, 225yds. E.S.E. of <i>Langness Farm</i> ; in Carb. Conglom. and Limestone	3½ft.	W. 20° N.	
"	Shore, E. side of Castletown Bay, W. of <i>Langness Farm</i> ; in Carb. Limestone	8ft.	N.W.	
"	Shore, E. side of Castletown Bay, N.W. of <i>Langness Farm</i> , 400yds. N. of last; in Carb. Limestone	4ft.	N.W.	
"	Shore, E. side of Castletown Bay, 100yds. N.W. of <i>Poyll Breinn</i> ; in Carb. Limestone	2ft. and 1ft.	N.W.	two dykes, or and parallel associated lenses; see p. 181
"	Shore, outer harbour, Castletown; in Carb. Limestone	branches, 3ft., 2ft. and 1ft.	N.W.	
"	Shore, 100yds. W. of harbour, Castletown; in Carb. Limestone	2½ft.	W. 25° N.	

¹ A list of the dykes of this district has been compiled and privately printed by Mr. B. Hobson.

No.	Locality.	Average Width of Dyke.	Average Direction of Strike.	Remarks.
19	Shore, S. of Castletown, opposite <i>Knockrushen</i> ; in Carb. Limestone Shore, S. of Castletown, 150yds. S. of <i>Knockrushen</i> ; in Carb. Limestone Shore, S. of Castletown, 80yds. S. of last; in Carb. Limestone Shore, S. of Castletown; old landing place opposite <i>Scarlet House</i> ; in Carb. Limestone Shore, S. of Castletown; " <i>Crag Kermode</i> ," at low water spring tides, opposite <i>Scarlet House</i> ; in Carb. Limestone	18ft. to 24ft., with sliers 6in. 6in. 2ft. ? base 80-90ft. wide, & dykes 8-10ft. wide	W. 10°-15° N. N. 15° W. N. 30° W. W. 5° N. ? W. 10° N.	much decomposed. perhaps connected with Carb. Volcanic series; see p. 325. Rock much obscured by seaweed. do. do.
20	Lheenah rio; low water reef in Castletown Bay Shore, 200yds. N. of <i>Scarlet Point</i> ; in Carb. Limestone Shore, in recess N. side of <i>Scarlet Point</i> ; in Carb. Limestone Shore, from 250yds. W. of <i>Cromwell's Walk</i> to within 200yds. of <i>Close ny Chellagh Point</i> ; in Volcanic Ash Shore, near northern termination of last, 30yds. and 50yds. further N. Shore, S. side of <i>Poyll Vaalish</i> , under <i>Fort</i> ; in Carb. Limestone and Ash Shore, S. side of <i>Poyll Vaalish</i> at "marble quarry" and thence across to low water S. of <i>Ghaw Gortagh</i> in Carb. Limestone and Ash Shore, S. and W. of <i>Poyll Vaalish</i> farm; in Carb. Limestone: three contiguous dykes Shore, S. of <i>Balladoole</i> , W. of <i>Poyll Rickie</i> ; in Carb. Limestone Shore, S. of <i>Balladoole</i> , W. of <i>Poyll Rickie</i> ; three small dykes Shore, S. of <i>Balladoole</i> ; at <i>Poyll Breinn</i> and across bay to <i>Strandhall</i> ; in Carb. Limestone Shore, S. of <i>Balladoole</i> , at <i>Poyll Breinn</i> , 50yds. N. of last; in Carb. Limestone Shore, east end of <i>Black Rocks</i> opposite <i>Kentraugh</i> , 150yds. W. of fault cutting out limestone Shore, east end of <i>Black Rocks</i> , 90yds. W. of last Shore, west end of <i>Black Rocks</i> , opp. <i>Kentraugh House</i>	see p. 325 4ft. 6ft. and two sliers 1ft. to 2ft. two small dykes or branches 9ft. and sliers 12 to 18ft. 5ft., 3ft., and 2ft. 3ft. may be prolonged 18ft. branching group thickest 3ft. 7ft. 1ft. 2ft.	N. 40° W. W. 30° N. N. W. N. 40° W. W. 40° N. N. W. N. 5° W. N. W. N. W. N. 25° W. N. 25° W. N. 30° E. and N. 20° W.	at margin of Volcanic series. traceable at intervals for distance of 750 yards. splitting into branches near low water traceable at intervals from middle of <i>Poyll Vaalish</i> to <i>Poyll Rickie</i> , parallel to and partly along fault. see p. 201, another dyke obscurely seen 80yds. farther south, at <i>Poyll Breinn</i> , probably connected with this. probably connected with last. cuts older dykes in slate. cuts older dykes in slate. ? diverted by a fissure.

CHAPTER IX.

THE GLACIAL DEPOSITS.

Introduction.

From its geographical position the Isle of Man offers an unrivalled field for the study of the conditions which have ruled in the northern part of the basin of the Irish Sea during the Glacial Period. The Island has, in fact, constituted a natural glaciometer, which has retained the marks of the successive stages of growth and decay of that great invasion of ice which has been the most remarkable episode in the later geological history of our planet. It is pre-eminently an area wherein the several theories by which the drift-phenomena of the Irish Sea basin have been explained may be put to the test.

In the present chapter it is proposed to give a general review of the Glacial geology of the Island, with descriptions of typical examples only of the phenomena, leaving the less important local details for record in a separate chapter.

The great development of 'diluvium' containing 'compound rocks not *in situ*'¹ in the northern part of the Island was fully recognised by the earlier investigators at the beginning of the present century. Macculloch ascribed it to diluvial action passing from south to north and leaving this material under the shelter of the Lills.² Henslow noticed that the hardened sand contained "fragments of shells and some perfect specimens of recent *cerithia*"; and also that the blocks from the Dhoon Granite did not occur north of the outcrop, and that the transport of the Foxdale Granite blocks indicated a current from north-east to south-west on the east side of the Island.³ In 1843 H. S. Strickland⁴ described the occurrence of shells in the drifts. Rev. J. G. Cumming was, however, the first to give an adequate account of the whole subject, which he did in his paper, published in 1847, on "The Geology of the Isle of Man. Part II. The Tertiary Formations."⁵ In this and his later works Cumming discussed the facts with his usual accuracy and acumen, showing that ice must have been the chief agent in the production of the drift deposits and the striation of the solid rocks beneath them. He drew especial attention to the dispersal of boulders of Foxdale Granite on the hill-range of South Barrule high above their parent mass, a subject afterwards discussed by Charles Darwin.⁶

¹ Geol. Trans., 1st ser., vol. ii., pp. 46-50.

² Account of the Western Isles, etc., vol. ii., p. 526.

³ Geol. Trans., 1st ser., vol. v., pp. 495 & 503.

⁴ Proc. Geol. Soc., vol. iv., p. 8.

⁵ Quart. Journ. Geol. Soc., vol. ii., p. 335.

⁶ Quart. Journ. Geol. Soc., vol. iv., pp. 315-323.

Cumming's classification of the superficial strata was as follows:—"1, Boulder-clay and erratic blocks; 2, Diluvium; 3, Drift-gravel; 4, Alluvium." As we shall see, his divisions correspond, in the main, to those adopted in the present work.

Among the later literature, Mr. Jno. Horne,¹ in 1874, contributed a short sketch of the subject in which he, for the first time, ascribed the deposits to *land-ice*; and Rev. J. Clifton Ward,² in 1880, published some useful notes. Mr. J. A. Birds,³ in 1875, and Mr. (Sir) H. H. Howorth,⁴ in 1877, added papers to the bibliography of the subject.

The latest paper to which I need here refer is that of Mr. P. F. Kendall,⁵ printed in 1894, which is the most valuable contribution to this literature since the time of Cumming. As this paper will receive frequent mention in the context, it is only necessary here to state that its leading conclusions have been confirmed by the fresh evidence now placed on record.

The drifts of the Island, as of all glaciated tracts, are profoundly influenced by the physical characters of the ground. The reader is therefore recommended at this stage to revert to the first chapter of this memoir, in which the physiography of the area is described, if he do not already possess a knowledge of the main facts therein stated. Except for the addition of the drift-plain of the north, the outline of the Island at the present day is not much different from its outline just before the Glacial Period. Its main valleys were then in existence and its sea-coast nearly corresponded with its present shores, except where these are now formed by drift-deposits.

We will now proceed to consider the facts under the following headings:—The Glacial Deposits and their fossils; Glaciated Rock-surfaces; Dry Rock-channels and allied phenomena; Transported Boulders; and Late-glacial Flood-gravels.

Composition of the Glacial Deposits.

Cumming and all the later observers have noticed that the drifts of the Island are separable into a high-level and a low-level series, the former consisting entirely of local material deposited among the hills either in the form of a hard bluish-grey till or as a looser slaty rubble; and the latter, largely composed of material foreign to the Island, usually either red stony clay or loam, or stratified gravel and sand, occupying the northern plain and the lower flanks of the hills.

In tracing out these divisions, however, it has been found that in certain localities the low-level series creeps up the gentler hillslopes to considerable elevations; and, on the other hand, that the high-level series descends in places to the plain; while along

¹ Trans. Edinb. Geol. Soc., vol. ii., pt. iii., p. 323.

² Geol. Mag., dec. ii., vol. vii., p. 1.

³ Geol. Mag. dec. ii., vol. ii., pp. 80-85.

⁴ Geol. Mag., dec. ii., vol. iv., pp. 410 & 456.

⁵ Yn Lloar Manninagh (Proc. Isle of Man Nat. Hist. and Antiq. Soc.), vol. i., No. 12, p. 397.

the flanks of the hills the two are inextricably interlocked. Hence it is by their lithological constitution rather than by their altitude that they are best distinguished, and we shall therefore designate them respectively, the Insular Drift, and the Extra-insular Drift; or they may be more briefly referred to as the Grey Drift and the Red Drift, from their prevalent tints.

The Insular Drift.

This material needs little description. It possesses the characters usual to the glacial accumulations of hilly districts. In the deeper valleys and on the upland plateaux it occurs chiefly in the form of tough till full of scratched stones of local origin; but on the hill-slopes, more often as loose clayey subangular rubble in which striated fragments are not plentiful. Both types are banked locally in thick masses in the lower and deeper portions of the valleys, but attain their widest horizontal extent in the shallow depressions around the heads of the drainage-systems, where they frequently sweep in smooth sheets up to and over cols at elevations of 1,000 to 1,400 feet. On parts of the central ridge of the Island, where the ground is not too steep for it to rest the rubbly drift rises still higher, occurring in little patches up to the highest summits. In some places where it ends off upwards against steep rock-slopes, as on the south-eastern flanks of North Barrule and Snaefell, and on South Barrule, this drift occasionally assumes a moundy form, probably due to the sliding down of the loose material in wet weather while the hill-side was yet bare of vegetation.¹ Where both types of the insular drift occur in the same section, as is often the case, the rubble almost invariably overlies the till.

There is no record of organic remains having been found in any portion of the Insular Drift.

That the local till is the product of land-ice would probably be granted by every field-worker in glacial geology, while many would hesitate to acknowledge the same origin for the shelly Extra-Insular Drift. Yet the inter-relations of the two series are such that whatever origin be assigned to the one can scarcely be denied to the other.

The rubbly drift is probably the *remanié* deposit of the ice-sheet largely modified by sub-aerial agencies. If there had been any submergence since glacial times this material could not have remained in the positions in which we now find it.

The absence of local moraines among the hills has been noticed by several observers. The explanation will, I think, be furnished in the context.

¹ I owe this suggestion to my colleague, Mr. G. Barrow, who has noticed the same feature in the Scottish Highlands.

The Extra-Insular Drift.

It is in regard to the Extra-Insular Drift that the peculiar interest and chief problems of Manx glacial geology arise. Its typical development is in the northern plain, where, fortunately, it has been carved out by the sea in admirable sections on both sides of the Island. The wasting cliffs thus formed are continuous on the western side for 8 miles, and on the eastern side for 6 miles, rising in several localities to elevations exceeding 100 feet, and in one place, at Point Cranstal, reaching over 200 feet. In the interior the chief exposures are to be found in the numerous old 'marl-pits,' whence clay has been dug for enriching the sandy tracts, and in a few small brickyards and sand pits; while the deep borings on the northern coast, described in Chapter VII., have incidentally revealed the deposit to an unexpected depth below sea-level.

This drift is of very variable composition, comprising both stratified and unstratified material, the former predominating. The cliff-sections generally show, at the base, red or purple boulder clay or loam, in which stones are not particularly abundant and are usually more or less rounded, but often beautifully striated; and above this, a considerable mass of stratified material varying in texture from fine laminated warp-clay to coarse bouldery gravel; while in the upper part of the cliff there is frequently another band of red clay with scattered stones. Of these divisions the last is perhaps the most constant, but the whole are so intermingled and so interchangeable that, so far as the beds above sea-level are concerned, we can scarcely escape from Mr. Kendall's conclusion, "that the Manx drift forms one great irregular series" (op. cit., p. 408). Though in some places the middle stratified beds repose upon an eroded surface of the lower boulder clay, in others there is a gradual passage, either with more or less stratification throughout the whole section, or with the boulders and stones of the lowest division set in a matrix of compressed unstratified sand which fades away into bedded deposits in all directions.

It is, indeed, by their mode of arrangement rather than by their lithological characteristics, that these Extra-Insular Drifts may be differentiated. They are in places spread out in almost level sheets, and in other places heaped up into mounds and ridges, as will be subsequently described.

Fossils of the Extra-Insular Drift.

The occurrence of marine shells in tolerable abundance in this drift is one of its chief characteristics. These are found both sporadically and in streaks and patches¹ in the lower boulder clay, but are more common in fine gravel among the middle stratified beds. So far as I have observed, they are invariably absent from the laminated warps and clays; and in the fine

¹ Kendall, op. cit. p. 410; see also pp. 342 and 428 of present work.

THE GLACIAL DEPOSITS.
Shells of the Manx Extra-Insular Drift¹ (all nat. size).

FIG. 80. *Astarte borealis*.FIG. 81. *Nassa serrata*.FIG. 82. *Nassa monensis*.FIG. 85.
Fusus cf. longiroster.FIG. 83. *Nassa Kermodei*.FIG. 84.
Fusus Forbesi.FIG. 86.
Trophon clathratum.FIG. 87. *Trophon (Fusus) Fabrici*, Beck (from E. Forbes,
Mem. Geol. Surv., vol. i., p. 424.)

¹ Figs 80-86 have been drawn by Mr. Gilbert Williams from specimens in the Geological Survey Museum; Fig. 80 represents a shell from the Post-Pliocene beds of the Clyde, as there was no suitable Manx specimen of this species in our collection; the others are from specimens from the Isle of Man.

nds are as a rule represented only by minute flakes and umbs. They are usually fragmentary, and much worn by trition. They present an admixture of forms from different pths of the sea, and also of northern and southern species. While most of the species are still living, eight forms occur hich are considered to be extinct (see list, p. 473).

These shells have been collected and worked out with eat care by Mr. P. F. Kendall, and the list given at the end of hapter XI. is reproduced from his above-quoted paper, with ight alteration and additions as duly noted.

In Mr. Kendall's opinion the beds in which these shells occur e not truly marine but represent the material of a sea-bottom istributed by an ice-sheet¹; and the general trend of the idence supports this conclusion.

It is probable that a portion of the original marine deposit as passed through in No. 6 Boring (see p. 342) at a depth of ver 200 feet below sea-level, consisting of 20 to 30 feet of uddy gravel and sand full of shells and foraminifera, differing many respects from any bed seen in the sections above sea- vel. This bed was not recognised in the borings farther estward, in none of which, however, was the drift found to tend to this depth (see p. 338; also details at pp. 418-21).

Boulders of the Extra-Insular Drift.

Large boulders of distant origin are of frequent occurrence in e Extra-Insular Drift, both among the stratified deposits and the boulder-clay, and are not found except in the area ccupied by this drift. They include, in the order of frequency, alloway Granite; Silurian rocks from the Southern Uplands, specially Queensberry Grit; Carboniferous Limestone; Carboni- rous Sandstone; Permian and Triassic Sandstones; with ccasional examples of Lake District rocks, Arran Granite, Pitch- zone, and a few others. At a rough estimate, it may be said that bout nine-tenths of these have had their parentage in the hilly outh-western corner of Scotland, and that the remaining tenth as been contributed by the Lake District, the Clyde Basin, nd perhaps the maritime part of north-eastern Ireland. These oulders range in size from a foot or less up to several feet in iameter.

Among the smaller stones are rather abundant pebbles of the iebeckite-rock (Paisanite) of Ailsa Craig, first discovered by Mr. Kendall; chalk-flints; several varieties of porphyrite; and an ccasional fragment of gneiss like that of Western Scotland (see pp. 420, 425 *et seq.* for details).

Mr. Kendall² has noted that the majority of the Scotch ranites seem to have come from Creetown and the Cairns mores, hough other varieties are present. The same observer is nclined to refer a few of the west-coast boulders to the granite

¹ Op. cit pp. 423-433.

² Op. cit., p. 406.

of the Mourne Mountains; and for the flint pebbles he inters a derivation from flinty gravels "which have lain in the path of the ice by which the Isle of Man was glaciated."

Among the rarer blocks brought to light by the researches of the Rev. S. N. Harrison of Ramsey,¹ are several boulders of gneiss; "the highly characteristic Porphyritic Pitchstone of Arran"; a granite and "the Felspar-porphyr of Bennan Head" from Arran; and the granite of Shap in Westmoreland. During the progress of the Survey a boulder of Shap Granite, 3 feet in diameter, was observed between tide marks in Perwick Bay near Port St. Mary, and another of the same rock at Wills Strand on the west coast north of Peel; also three or four large blocks probably from the Borrowdale Series of the Lake District, one on Maughold Head, a second near Ballameanagh on Clay Head, and a third on the northern plain at Lagagh Mooar. It is probable that these rarer erratics have in the first place been distributed over the sea bottom by floating ice, and afterwards dragged forward from their marine bed by the advancing ice-sheet (see p. 345); while the Galloway Granites and other Southern Upland rocks are more likely to have been directly transported by a stream of land-ice leaving the Scottish coast around Luce Bay as indicated by the glacial striations of that district and of Manxland.

Typical Sections of the Extra-Insular Drift.

To illustrate the general character of the drifts of the northern plain, three sections have been selected, from the cliffs of the eastern and of the western coast, and from the No. 6 Boring. The first, Fig. 88, which lies $2\frac{1}{2}$ miles northward from the nearest part of the Manx Slate massif, shows a predominance of stratified material; while the second, Fig. 89, on the west coast, half-mile north of the nearest slate outcrop, exhibits the lower boulder-clay as its more prominent constituent; but in both instances these relative proportions of stratified to unstratified material are only local and are reversed in other sections not far distant.

The section in Boring No. 6, given on pages 340-41, shows a downward succession of the drifts below tide-mark from about the level of the base of the above cliff-sections. Of the three borings, Nos. 4, 5, and 6, in which the opportunity occurred for closely investigating the drift by washing and sifting the material from different depths, the records of Nos. 4 and 5 will be found on pp. 418 and 419, and contain some points of interest not observed in No. 6, but show a much less thickness of drift. A depth of only 173 feet of drift was found in No. 4, and of 212 feet in No. 5, against an approximate depth of 476 feet in No. 6, the deeper beds of the last boring apparently not being

¹ See *Yn Lloar Manninagh* (Journ. Isle of Man Nat. Hist. and Antiq. Soc.), vol. i., p. 375, and vol. iii., p. 21.

FIG. 88. *Cliff-section in glacial drift at Kionlough
2 miles north of Ramsey.*

Scale : 1 inch = 40 feet.

- | | Thickness |
|---|-------------|
| 5 Blown sand and gravelly rainwash | 3 to 5 feet |
| 4 Stratified gravel and sand = Upper Platform Gravel - - - | about 15 „ |
| 3 Reddish warp and clay, more or less stratified; rather stony in the upper part; passing downwards into— - - | „ 20 „ |
| 2 Well-stratified sand with gravelly layers and streaks of red clay; calcareous concretions in places. Shell-fragments abundant in the finer gravel but absent from the sand and clay - - - | 50 to 60 „ |
| 1 Red warp or clay with a few stones, at foot of cliff - - - | about 5 „ |



FIG. 89. *Cliff-section in glacial drift at the southern side
of Orrisdale Head, 1 mile north of Kirk Michael.*

Scale : 1 inch = 40 feet.

- | | Thickness. |
|--|---------------|
| 5 Blown sand - - - | about 5 feet. |
| 4 Stratified sand, etc., with band of red clay in places, not well seen | „ 15 „ |
| 3 Stratified sand, warp and fine gravel, contorted in places; a few shell-fragments in the gravel | „ 20 „ |
| 2 Coarse bouldery gravel, cross-bedded; thickening northward and there resting on an eroded surface, but here thinning out and apparently passing into— - | 0 to 10 „ |
| 1 Rudely stratified and contorted sandy boulder-clay or loam, containing many boulders and scratched stones of extra-insular origin, especially towards the top; also a few small fragments of slate, possibly Manx, and a few shell-fragments - - - | 30 to 40 „ |



represented in the other sections. Except in regard to these deeper beds, viz., those below 215 feet, the general character of the drifts of the above-mentioned borings resembled that of the cliff-sections; the erratic stones were of the same kind; the shell-fragments occurred in the same manner and were of the same species, though somewhat differently grouped (p. 421); the clays and sands were similar in composition; and there was the same absence of peaty material and of any indication of a break or change in the climatic conditions.

The beds below 215 feet in No. 6 Boring are, however, exceptional and deserve careful consideration. Between the depths of 220 and 240 feet the material, as previously stated, represents a marine deposit of glacial age, either an accumulation in place or a large displaced mass embedded in the drifts like the well-known instances in East Yorkshire. As the lower part of the section includes much local drift, apparently non-marine and probably due to the agency of land-ice, and as the drifts above sea-level are almost certainly of similar origin, it follows that if the marine bed be actually in place we must allow two distinct invasions of land-ice separated by an interval of open sea; and for this there is no other evidence in the Island.

Between 240 and 363 feet the boring passed through sands and gravels below the marine horizon, which, judging from the only sample that was preserved, appear to have represented stratified glacial material like that above sea-level; but our information respecting this part of the section is unfortunately inadequate. Below 363 feet the material was apparently a local boulder-clay made up from the subjacent Triassic Marl mingled with a few extraneous pebbles. From the specimens examined, the thickness of this bed appears to have been not less than 65 feet, and may have been much more, the marls being crushed and in places mixed with extraneous pebbles for at least 50 feet deeper (if the material supplied to us was correctly labelled) and partly reconstructed for a further 50 feet. As the boring was tubed down there seems no probability of the pebbles having been introduced accidentally from above; and the crushed condition of the marl in the specimens bore out the other evidence.

Section of Glacial Drift in No. 6 Boring, Point of Ayre.

From the Engineer's Journal; with additional descriptions in square brackets.

	<i>Ft.</i>	<i>in.</i>
Shingle - - - - -	16	0
[Raised Beach.]		
Gravel - - - - -	32	0
Sand and gravel - - - - -	8	0
Sand - - - - -	12	0

[No samples of the above beds were obtained.]

Sand and gravel -	<i>Ft.</i> 37	<i>in.</i> 0
[Sample of the gravel at depth of 100 feet contained shell-fragments, including <i>Mytilus</i> with <i>Serpula</i> ; also a pebble of dark blue grit, 2 inches in diameter, encrusted with nullipores and <i>Serpula</i> , and with indurated sand, full of shell-fragments, adherent to it; another pebble, of vein quartz, 1 inch in diameter, similarly encrusted, with polyzoa; also some small pebble-like fragments of indurated sand with bits of shell.]		
Hard sand - - - - -	8	0
Clay - - - - -	27	0
[Sample at 130 feet consisted of dark purplish brown clay with small foreign stones; like that seen at foot of cliff at Point Cranstal (see Boring No. 4, p. 420, for further description of similar material).]		
Sandy clay - - - - -	8	0
Sand - - - - -	6	0
Sandy clay and stones - - - - -	10	0
[Sample at 160 feet; a pebbly clay, similar to that at 130 feet, but mixed with more sand and grit; effervesced freely with acid]		
Reddish clay - - - - -	3	0
[Sample at 166 feet; smooth dark brown clay without stones or grit; probably like laminated warp-clays of cliff-sections: effervesced freely with acid.]		
Sandy clay - - - - -	5	0
Sandy clay with stones - - - - -	10	0
Sandy clay - - - - -	20	0
[Sample at 190 feet; fine brown sandy clay or silt, without stones or shells; probably 'laminated warp': effervesced freely with acid.]		
Sandy clay with stones - - - - -	13	0
[Sample at 206 feet; purple clay, with pebbles of dark blue grit and vein-quartz 1 to 1½ inches diameter; also a shell-fragment; effervesced freely with acid.		
Another sample marked "between 202 to 215 feet"; dark greenish-purple sandy clay with stones; on washing, yielded pebbles like last, with one of pink felsite, ½ inch diameter; the finer siftings consisted of dark gravel with small much worn shell-fragments including <i>Mytilus</i> and <i>Mactra</i> .		
Another sample marked "215 to 220 feet"; similar material to last; pebbles included piece of slate, 1½ inches diameter, which might be <i>Manx</i> ; finer siftings contained many angular shell-fragments, including <i>Astarte compressa</i> , <i>Rhynchonella</i> , <i>Nucula</i> or <i>Leda</i> , <i>Mactra</i> , <i>Balanus</i> , etc. This material seems to mark the top of the marine bed.]		

Silt	- - - - -	Ft. in. 5 0
[Sample at 218 feet; greenish sandy mud or clay with small pebbles, full of crushed shells with the fragments angular and in proximity to each other; material resembles the shelly streaks in the drift at Bridlington and Dimlington in Holderness.]		
Gravel with shells	- - - - -	1 0
[<i>Mytilus edulis</i> largely predominant; <i>Tellina balthica</i> ; <i>Astarte sulcata</i> var. <i>elliptica</i> ; <i>Natica</i> sp.; <i>Buccinum undatum</i> . Pebbles; dark green trap encrusted with nullipores and containing <i>Saricava rugosa</i> in a hollow; two pebbles, each of 1 inch diameter, completely encrusted with nullipores and <i>Serpula</i> ; basalt, grey micaceous grit, and dark grit, from 1 to 1½ inches diameter, with patches of nullipores; hard cherty chalk, 1½ inches (from Antrim ?); flint; slate, possibly Manx, 3 inches; pale pinkish felsite, 1½ inches diameter.]		
Sand	- - - - -	7 0
[Sample at 221 to 228 feet; fine yellowish grey sand with many foraminifera and small fragments of shell; on sifting, the only residue a few grains of dark grit and fragments of <i>Rhynchonella</i> , <i>Balanus</i> , etc.]		
Muddy sand with shells	- - - - -	12 0
[Sample marked '228 to 240 feet'; 'reamy' ¹ sand full of shells, fragments of <i>Mytilus</i> and <i>Balanus</i> predominating; on sifting, yielded—		
<i>Mytilus edulis</i>	<i>Trophon clathratus</i>	
<i>Astarte sulcata</i>	<i>Bamffius</i>	
——— <i>compressa</i>	<i>Turritella terebra</i>	
——— <i>borealis</i> (young)	<i>Buccinum undatum</i>	
<i>Mya truncata</i>	<i>Natica clausa</i>	
<i>Tellina balthica</i>	<i>Lacuna divaricata</i>	
<i>Rhynchonella psittacea</i>	<i>Balanus Hameri</i>	
	——— <i>crenatus</i> .	
Sample from 238 feet; sandy mud full of shell-fragments of a different facies from the above, <i>Rhynchonella psittacea</i> being the commonest shell and <i>Mytilus</i> rare or absent; the shell-fragments frequently coated with polyzoa; no gravel except a few worn grains not larger than ½ inch diameter; residue on washing, nearly all bits of <i>Rhynchonella</i> and polyzoa; the only shells recognised besides <i>Rhynchonella psittacea</i> were <i>Astarte striata</i> and <i>Cardita</i> ?]		
Reddish sand	- - - - -	36 0
[Sample marked 240 to 276 feet; reddish yellow or brown sand, becoming paler and greyish on washing; on sifting, very little residue, consisting of a few		

¹ "When there is a considerable admixture of mud with coarse sand, forms what is known to the trawlers as a 'reamy' bottom." See "Marine Biology of the Isle of Man," by Prof. W. A. Herdman, in "Handbook Liverpool: British Association, 1896," p. 187.

Ft. in

dark rolled grit grains the size of small shot, some highly polished grains of quartz-sand like those of the Permian Sandstone of No. 4 Boring (see p. 285), and some indeterminable crumbs of shell; also a few foraminifera. Probably not a marine sand.]

Sand and gravel	- -	- - - - -	2 0
Ditto with pieces of coal		- - - - -	2 0
Gravel	- - - -	- - - - -	35 0
Coarse gravel with clay	-	- - - - -	9 0
Reddish sand	- - -	- - - - -	24 0
Gravel	- - - -	[No samples preserved]	6 0
Stone	- - - -	- - - - -	0 8
[Apparently a large boulder ; no specimen seen.]			
Gravel and sand with clay	-	- - - - -	8 4

Disturbed Marls 181 feet :—

Red marl with stones and gypsum - - - - - 65 0

[Sample at 380 feet ; dull red clay with pebbles ; effervesced with acid ; on washing, yielded pebbles—dark (Carboniferous ?) limestone, 2 inches diameter ; well-rounded quartzite, same size ; and smaller bits of limestone, dark grit, etc. : no shell-fragments : fine residue contained small gravel of quartzite, vein quartz, and various dark and reddish rocks, with some bits of gypsum : seems like a boulder-clay largely composed of red marl, different from any seen at surface.]

Sample at 426 feet ; like last, but contained a piece of gypsum of 2 inches diameter ; gravelly residue on washing, coarser than last, contained dark limestone, brown and red sandstones (New Red rocks ?), gypsum (rather abundant), marly slate, black and dark purple grits, fragment like Ailsa Craig rock (½ inch diameter), polished grains of vein-quartz, etc. ; no shells.

Sample at 427 feet ; like last ; gravelly residue contained dark limestone, quartzite, quartz, gypsum, flint, greenish sandstone, dark grit, etc.

Sample at 428 feet ; clay, red dappled with pale grey ; did not effervesce with acid ; residue, small gravel like above, of well-rounded quartzite and quartz, gypsum, red felsite, etc., etc.]

Brown marl with gypsum - - - - - 72 0

[Sample at 453 feet, and another, similar, at 462 feet ; red and grey marl with crystals of gypsum, disturbed but not crushed down like that below ; on washing, sunk into a red mud with rounded bits of gypsum but no extraneous material ; may be a displaced mass of the Triassic marl.]

Ft. in.

Sample labelled 476 feet; marl crushed down into clay, with some subangular foreign stones; the following pebbles obtained on washing:—dark sandy slightly calcareous shale, 2 inches by 1½ inches; pale grit with faint markings like glacial striae, 1½ inches; and smaller pebbles of vein-quartz, pale chert or flint, gypsum, dark limestone, dark sandy shale with cast of a fossil, etc.; fine residue, a small quantity of speckled sand made up of materials similar to the pebbles. This seems to be a local boulder-clay like the specimens at 427 and 428 feet. If the specimen be correctly labelled it indicates the presence of extraneous drift material among the disturbed Triassic marl at this depth.

Samples at 485 feet and 498 feet; crushed red and grey marl, with a pebbly structure as if reconstructed; residue on washing, bits of marl and gypsum only.]

Gypsum mixed with sandy marl	-	-	-	-	-	2	0
Brown and grey marl mixed with gypsum	-	-	-	-	-	42	0

[Samples examined at 523, 535, and 541 feet showed disturbed red and grey marl (with crystals of salt in the deepest example) in which bedding was scarcely recognisable; yielded no extraneous admixture when washed and sifted.]

Stratified saliferous marls, etc. (see p. 290 and Appendix, p. 585)	-	-	-	-	-	-	378	4
Total depth of boring	-	-	-	-	-	-	<u>920</u>	<u>4</u>

The site of the above boring is on the outer edge of the Post-glacial Raised Beach (see Chap. VII., p. 283). On the inner or southward edge, this Raised Beach is bounded by an old marine cliff, which has been carved out of a high platform of glacial drift (see Fig. 96, p. 355). This drift-platform has evidently once extended much farther northward, so that its height above sea-level should be added to the depth proved below sea-level in estimating the original thickness of the drift in this locality. In the present cliff at Point Cranstal, two miles south of the boring, the drifts attain a thickness of about 250 feet, but their average is much lower, and we probably ought not to allow more than an additional 80 to 100 feet for their original development above sea-level at the borings. This would give an approximate initial thickness of between 525 and 575 feet for the drifts near the Point of Ayre before their erosion; and they probably still attain not less than this depth in the hills around Kirk Bride (see diagram, Fig. 96), a thickness, I believe, nowhere surpassed in the British Islands.

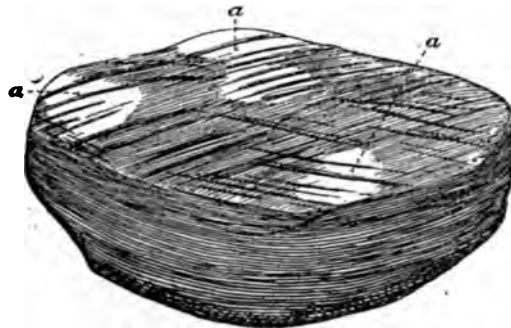
The discovery, from the borings, that the drifts rest upon a disturbed floor of soft Triassic marl and sandstone in the north of the Island, with the inference that similar conditions obtain over a large area in the adjacent part of the Irish Sea basin

(p. 289), is sufficient indication of the source whence most of the material of the red drift has been directly or indirectly derived. The marine bed found in No. 6 Boring, with its far-transported pebbles encrusted with polyzoa and serpulæ, when taken along with other evidence, goes far towards proving that a sea in which arctic conditions prevailed has existed in this basin during an early stage of the Glacial period; and the subsequent ice-sheet seems to have incorporated the marine detritus of this sea with the debris of the Red Rocks and with material transported directly from the Galloway uplands, to form the drifts above sea-level.

Indications of the redistribution of material from a glacial marine bed are frequently afforded by the boulders of the drift. For example, a block of Carboniferous Limestone, measuring $2\frac{1}{2}$ feet by 2 feet by $1\frac{1}{2}$ feet, lying in 1894 on the north side of Orrisdale Head, at the foot of the cliff of drift from which it had recently fallen, was encrusted in places with hardened shelly sand, with glacial striations traversing this incrustation as well as

FIG. 90. *Glaciated Carboniferous Limestone Boulder encrusted with shelly sand and afterwards again glaciated.*

Scale : $\frac{1}{2}$ nat. *a, a, a*, incrustations of shelly sand.



the limestone, as shown in Fig. 90. After its first glacial transportation this boulder must have lain in a matrix of shelly sand, presumably on the sea-floor, and must subsequently have been caught up and reglaciated, to be finally incorporated in the upper part of the drift. The same story was told by a subangular fragment of the Ailsa Craig riebeckite-rock $1\frac{1}{2}$ inches in diameter, which was found encrusted with nullipores at a depth of 165 feet in Boring No. 4 (see p. 420).

Relations of the Extra-Insular to the Insular Drift.

The relation of the shell-bearing drift of the northern plain to the slaty hill-drift is fortunately exhibited in cliff-sections on the flanks of the hills on both sides of the Island.

FIG. 91. *Cliff-section south of Ballure Glen, Ramsey, showing interbedding of local and foreign drift-material.*

Scale, hort. and vert., 1 inch = 100 feet.



- 11 Rough semi-stratified clayey slate-rubble and gravel : = Local rubble-drift : capped in places by thin silty wash.
- 10 Irregular band of red clay with a few pebbles : = Extra-insular drift : appears to thin southward into underlying gravels.
- 9 Fine slaty gravel and silt, with a few foreign pebbles ; thin streaks of red clay in upper part at N.W. part of section.
- 8 Streaks of red clay among slaty gravel and silt, probably represented by red boulder clay farther north.
- 7 Cross-bedded sand, loam and fine gravel ; pebbles partly of local slate and partly of foreign material ; thins rapidly southward.
- 6 Irregular band of stony red clay, fading out in places : = Extra-insular drift. Probably continued southward (6 ft) among local till (4).
- 5 Dark slaty gravel and sand with a few foreign pebbles.
- 4 Bluish slaty till : = Local drift.
- 3 Stratified cross-bedded yellow sand and gravel, contorted in places ; pebbles chiefly local but foreigners abundant, including Ailsa Craig riebeckite-rock.
- 2 Grey slaty till, with an occasional extra-insular stone : = Local drift, with foreign admixture.
- 1 Coarse rubble of slate-fragments, banked against old cliff and in small hollow on top.
- x Manx Slate forming pre-glacial cliff.

NOTE. — Unshaded portions of section not seen ; dotted boundaries obscure.

On the eastern coast the plain ends off against the massif immediately to the southward of the town of Ramsey, and a fine cliff-section shows very clearly the interdigitation of the foreign with the local drift. Although this section has been previously figured by Mr. Horne and again by Mr. Kendall, it is of sufficient importance to be worth refiguring, especially as it is now less obscured by talus than formerly. (Fig. 91.)

The solid slate-rock descends below sea-level at the foot of the old cliff on the S.E. side of this section, and there appears to be a pre-glacial tidal rock-shelf below that of the present day. This shelf is covered with red boulder-clay containing shell-fragments, resembling upper beds 6 and 10 of the section, and this material, when not hidden by modern beach-stuff, may be traced down to low water, and along the shore eastward for half mile to Port Lewaigue. Between this strip of clay and the present cliff of slate there intervenes a narrow rock-bench which marks the extent of coast-erosion which the slate has undergone since Glacial times (see p. 123). At Port Lewaigue the red boulder-clay passes inland across the promontory through the depression between Maughold Head and the hills to the westward, and reappears in the cliffs at Port Mooar. On the rocky ridge of Maughold Head itself foreign boulders are rather abundant, but do not attain the same elevation on the slope west of the depression. Farther south we find patches of the red drift here and there along the bold coast wherever the ground is not too steep, either in the form of stony clay or of gravel with many foreign stones; and where, as at Garwick and at Onchan, a depression strikes inland approximately parallel to the hilly axis of the Island, the foreign material passes up along it for a short distance, gradually merging into the local drift. That this train of extra-insular drift marks the direction taken by moving ice on the south-eastern side of the hills is confirmed by the orientation of the glacial striæ on the solid rocks (see p. 476). A patch of the red clay has lodged on the northern slope of Clay Head, the promontory jutting out on the southern side of Laxey Bay; and again in the recess of Douglas Bay; and in various places around Santon (St. Ann's) Head. But to the southward of a line traversing the Island from Santon on the east coast to Cronk ny Arrey Lhaa on the west—that is to say, around the south-western or leeward end of the main hill-ranges—no clear distinction can be drawn between the local and the foreign drift; and instead, there is, in nearly every section, a small proportion of extra-insular material incorporated with the local detritus which forms the bulk of drift.

On the western side of the Island the phenomena are similar, excepting that separable red drift extends for several miles farther southward, and also rises to higher elevations before merging with the local material. This we should expect, since the glacial striæ on the highest ground of the Island show that the ice-movement, where free from local deviation, was from north-north-westward, the western slope being thus the 'stoss'

side of the hills. On the west coast there is a steadily-increasing quantity of local slaty material among the shelly gravels of the red drift southward from Orrisdale Head; but it is not until we reach the first outcrop of the slate rocks at Gob ny Creggan Glassey, nearly 2 miles south of Kirk Michael, that any local till

FIG. 92. *Diagram showing replacement of stratified shelly drift by local boulder-clay in the cliff-section near Gob ny Creggan Glassey, Kirk Michael.*

Scale, for both Figs. : 1 inch = 100 feet, hor. and vert.

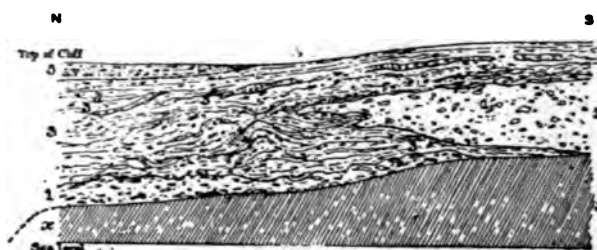
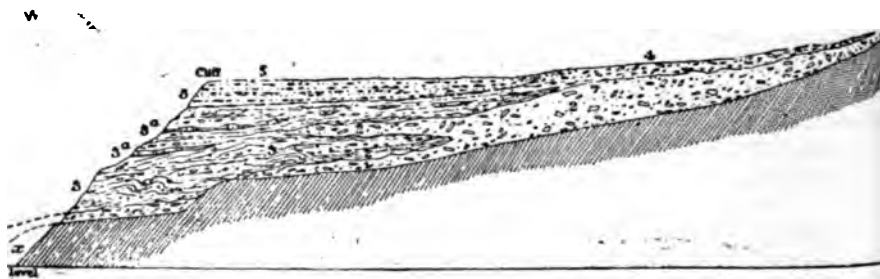


FIG. 93. *Diagram at right angles to the above, showing general arrangement of the drift deposits on the lower slopes of the hills; based on sections in Glion Thoor and Glion Shellan.*



EXPLANATION (for both sections).

- 5 Stratified slaty platform-gravel, probably passing into (4) at foot of slope.
- 4 Upper local rubble-drift.
- 3 Stratified extra-insular drift; cross-bedded and confused in places; composed of sand, silt, gravel, with a few shell fragments, and thin patches of red clay, 3a, towards the top; the gravel, a mixture of local and foreign material.
- 2 Dark grey or blue local till, with a few foreign stones.
- 1 Slaty rubble passing in places into dark slaty till (2).
- x Manx Slates.

is developed in the coast-section. Between this place and Glen Mooar the interdigitation of the insular and extra-insular drift is as well marked as at Ramsey, though the sections are somewhat overgrown and difficult of access. The main facts are as shown in the foregoing diagrams, the one representing the section parallel to the cliff-line, and the other that at right angles to it. (Figs. 92 and 93.)

The structure shown in the above sections is prevalent, with local modifications, in most of the drift of the hill-slope bordering the coast for the next two miles southward; but south of Wills Strand, where there is a lower tract occupied by the Peel Sandstones, the red drift occurs alone, chiefly in the condition of boulder-clay. This low tract is margined on the east by steep inland bluffs of slate, which terminate rather abruptly at the valley of the Neb near St. John's; it is also bordered by steep hills of slate along its westerly edge south-west of Peel, and by similar hills to the southward between Kirk Patrick and the south bank of the Neb at St. John's, where rises the mountainous ground of Slieau Whuallian (1,094 feet). The low sandstone tract is thus encircled with high ground on all sides except the seaward, in which the only gaps are the valley at St. John's and a low dry col south of Kirk Patrick which has probably once carried the drainage of Glen Rushen (see page 10). The distribution of the red drift around this cul-de-sac seems necessarily to imply the presence of a great south-moving ice-sheet in the basin of the Irish Sea.

To the south and west of Peel the red drift, somewhat gravelly and intermingled with local material, sweeps up through the gap at Kirk Patrick into Glen Meay, where it joins with the similar drift which covers the lower flanks of the hills bordering the coast southward to Dalby. Eastward it spreads up the depression as far as St. John's, patches of red boulder-clay containing many fragmentary marine shells being visible in the bed of the Neb at the mouth of Glen Mooar. At St. John's three valleys unite, that of the Neb coming in from the north, that of Foxdale from the south, and the central valley of the Island from the east (p. 458). Into the first the red drift does not penetrate beyond the mouth; into the second it enters for only a short distance, and then dovetails out among the local drift in a manner well shown in the river-bank one mile south of St. John's, as illustrated over-leaf in Fig. 94.

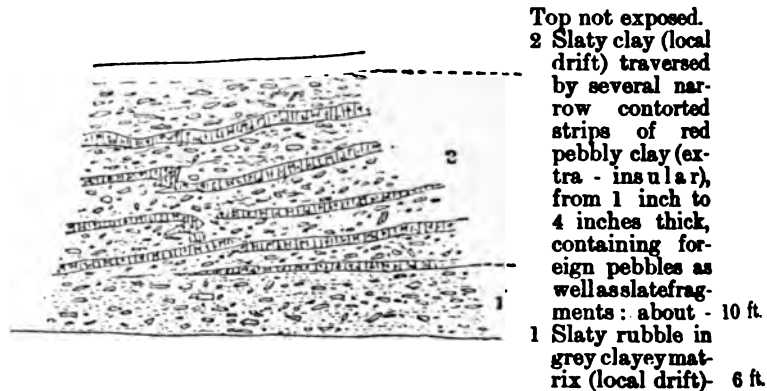
In the bottom of the central valley the drift is buried deeply under alluvium and terrace-gravels, and is not seen; but on the lower part of the hill-slopes yellow sandy reconstructed drift containing foreign boulders and pebbles mixed with local material can be traced eastward as far as the narrow pass at Greeba, while among the hills to the northward the drift is all of insular origin. The central watershed of the Island lies a little to the westward of the Greeba pass, at an elevation of only 160 feet above sea-level; but though the foreign drift crosses the summit, it appears not to have descended the valley east-

ward beyond Greeba, and all the glacial material visible between Crosby and Union Mills is of local origin, except a few far-transported pebbles occurring in old flood-gravels lining the valley (p. 459).

Thus, so far as the valleys are concerned, the foreign drift fairly well maintains its character as a low-level deposit, the only remarkable point being its failure to find passage farther along them. But this character is quite lost on the hill-slopes to the south-eastward of St. John's, where we unexpectedly find that the red drift rises out of the valley and sweeps in a broad

FIG. 94. *Drift-section in the west bank of the Foxdale River, opposite Ballahig, showing interlamination of red (extra-insular) and grey (insular) boulder-clay.*

Scale : 1 inch = 20 feet.



belt south-south-eastward up the gentle incline which forms the shoulder between Foxdale and the central valley, and spreads out on the summit at a higher elevation than it attains in any other part of the Island.

The drift occurs on the slopes and summit of the incline in the form of yellow clayey sand or loam, containing many rock-fragments foreign to the Island along with others of local derivation. This material lies thickly in a shallow depression on the summit of the ridge at an elevation of 600 feet above sea-level, underlying the northern part of the tract newly planted with trees; and spreads southward more thinly nearly to the highest portion of Archallagan, the rounded summit beyond, reaching an altitude of about 700 feet. Glacial striæ are of rare occurrence in this district owing to the unfavourable character of the country-rock for their incision, but it happens fortunately that one finely-scratched surface of slate is revealed underlying the drift with foreign stones, in a little water-channel in Archallagan plantation 200 yards south-east of the old Cornelly or

Townsend Mine (p. 459). These striæ are directed from N. 35 W. to S. 35 E.; and on facing this direction we look straight through the gap in the hills at St. John's and across low ground to the open sea. Large boulders of Galloway granite, one of which is 8 feet in diameter, are dotted over the path of the drift on the high ground, and there are also many smaller erratics, including Silurian grit from the Southern Uplands, red porphyry, diabase, and others—in fact, the usual assemblage found in the extra-insular drift. These are numerous in the vicinity of the above-mentioned old mine, and many have been carried down into Glion Darragh, the steep rocky gully below the mine. (See further details on p. 459.)

It seems impossible to explain the position of the red drift in this tract except by granting that, like the local drift, it has been the product of an ice-sheet which has overwhelmed the hills. Its distribution is then seen to depend directly upon the configuration of the surrounding district. The abrupt slopes of Slieve Whuallian immediately south of St. John's have been too steep for the drift-laden basal layers of the advancing ice-sheet to surmount, and rock-slopes nearly as steep have similarly hemmed it in on the north-eastward, leaving a narrowing gap, like the base of a funnel, for the passage of the lower part of the ice, with a gentle incline leading upward from the orifice. With land-ice pressing in across the open ground to the north-north-west in the direction indicated by the striæ, and the valleys already partly occupied by local glaciers (see p. 391), we realise easily the conditions of glaciation at this place; whereas under the supposition of the marine origin of the red drift, the facts would be inexplicable.¹

After crossing the main watershed of the Island at Archallagan the extra-insular drift becomes less distinct, owing to the greater admixture of local detritus; but it may be traced, hugging the ridge for about a mile farther, to the high ground above Garth, by the presence of its far-transported boulders in the walls and fences.

Its individuality as a stream is then lost, probably through its having been caught in the south-westerly drag of the ice under the lee-side of the hills (p. 347); but its gradual dissipation in this direction may be held accountable for the presence of a few foreign pebbles in the local drift of the east bank in the upper valley of the Santon River.

Other examples of a similar though less extensive dragging up of the foreign drift to high levels will be described in the subsequent chapter.

Though differently attained, the same conclusions are implied in the relations of the drifts at the mouths of the valleys which break the bold scarp-like northern termination of the mountains

¹ It would be waste of space to consider, as a possible alternative, the recently revived "waves of translation" hypothesis of drift-formation; it is negatived by the whole tendency of the evidence in every part of the Island.

between Ballaugh and Ramsey in the north of the Island. These valleys—Glen Dhoo, Sulby Glen, and Glen Auldyn—are pre-glacial, and trench into the solid rocks deeper than the level of the present drift-plain; and the red drift is banked continuously along the front of the hills at higher levels than the valley-floors. They all contain much glacial detritus, and in Glen Auldyn and Sulby Glen this apparently consists entirely of local material, the foreign drift barely entering their mouths. In Glen Dhoo, however, there is yellow sand and gravel with foreign stones and streaks of red clay as far up as Riversdale, about a mile from the entrance, and the local drift is confined to the upper reaches of the valley. This difference may be explained by the fact that the two former glens possess open drainage basins among the hills, while the last is only a deep trench cut back into the end of a ridge and terminates in a coomb, as can be gathered at a glance from the hill-shading on the one-inch map. The glens with extensive upland catchment-areas were probably blocked with local glaciers at an early stage in the Glacial period, so that no room was left for the extraneous ice when the Island was afterwards enveloped in the south-moving sheet; but Glen Dhoo and one or two similar valleys in other parts of the Island were partly unoccupied from lack of sufficient gathering ground, and were therefore filled up by a tongue of the main ice sheet.

Again, on the western coast south of Dalby the hills are for the most part too high and abrupt for any drift to have lodged; but where the range is gapped by depressions, as at Fleshwick and at Port Erin, the red shelly drift has entered in upon the land in a stream which mingles gradually with local detritus. (See pp. 461 and 471 for local details.)

The above facts are throughout consistent with the view that the accumulation of the extra-insular drift on the low ground and flanks of the Island has been practically contemporaneous with that of the local drift in the interior; and that both are the product of land-ice. Their relative distribution is everywhere in keeping with Mr. Kendall's supposition that only the lower layers of the ice-sheet were drift-laden,¹ and that these were diverted by the steeper hill-slopes and swept round the flanks of the massif as an undercurrent. As will presently appear, this view is borne out by other evidence, especially by that of the glacial striations and the transport of local rocks in the Island. It is likewise entirely consonant with the result of recent investigations of existing glaciers in Greenland² and Spitzbergen.³

¹ Op. cit., p. 426.

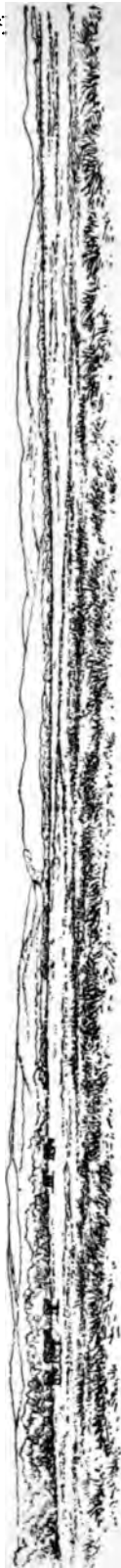
² Prof. T. C. Chamberlin, Bull. Geol. Soc. America, vol. vi. (1895), 190-220; and Journ. Geol. of Chicago, vols. ii., iii., and iv. Also G. H. Barton, Technology Quarterly, vol. x. (1897), pp. 213-244.

³ E. J. Garwood and J. W. Gregory, Quart. Journ. Geol. Soc., vol. liv, pp. 197-227; and E. J. Garwood, *ibid.*, vol. lv., pp. 681-691.

Topographic Features of the Extra-Insular Drift.

In all questions relating to the origin of the drifts, the topographic forms which the deposits assume are of at least as great importance as their lithological composition. This is strikingly exemplified in the Isle of Man, where the study of the surface-features yields much more information as to the conditions of accumulation of the drifts than can be obtained from the most careful examination of the cliff-sections.

Near the northern margin of the drift-plain the extra-insular drift is heaped into a chain of mounds or ridges, rising suddenly from a level plateau to a height of from 200 to 300 feet above sea-level. This chain, rarely more than $\frac{1}{2}$ mile in width, sweeps round for twelve miles in a rude crescent, from the east coast at Bride to the west coast at Jurby and Orrisdale. The feature was known to the geologists of the early part of the century as the Ballachyrrim Hills, but this name has been displaced by the term Bride Hills, applied by Cumming and the later writers from the village which shelters under the eastern summit. As seen from the low ground to the southward (see Fig. 95) the chain seems at first sight to be continuous; but on closer investigation it is found to be composed of three or more segments set *en échelon*. The encroachment of the sea has carried away most of the ground on the northern or convex side, and has destroyed the eastern horn of the crescent and also broken through the western margin at Ballakinnag; but there is still a strip of lower drift land lying to the north of it between Kirk Bride and Ballamacskelly. On its southern or concave side the drift deposits are arranged in a series of plateaux, mainly composed of gravel, which either slope gently inward or descend by two or three distinct steps to the boggy alluvial hollow, known as The Curragh, under the bold slopes of the old massif. These plateaux are furrowed by numerous drainage hollows, now for the most part dry or occupied only by artificial drainage trenches; and these channels, with one notable exception, descend inward towards the Curragh even when, as at Dog Mills, 2 miles north of Ramsey, the head of the channel is quite close to the existing coast.



Stratified material predominates in the composition of the ridges, especially on the concave side of the crescent; but they also contain much stony red clay or boulder-loam, only in part stratified, especially on the northern slope where this is occasionally the chief constituent. On the published drift-map the sand and gravel of the mounds has been indicated by a deeper tint than the similar material of the plateaux, and the outline of the hills is partly defined thereby. Where, however, the boulder-clay forms part of the hills, as around Kirk Bride, this is shown by its proper colour, and a dotted line has been drawn to mark off the northern limit of the ridges.

The structure of the interior of the mounds is excellently revealed in the cliff-sections at Point Cranstal on the east and at Orrisdale Head on the west. These show that the hills are chiefly due to the local thickening of the middle or stratified part of the drift-series. The lower boulder-clay is usually found at the base of the cliff, passing under the mounds without much change of level; while above it the rest of the section is made up of a confused pile of coarse current-bedded boulder-gravel, fine shelly gravel, sand, warp, and stony loam, frequently contorted, though generally well stratified. At Point Cranstal the cliff-section is nearly at right angles to the ridge, and is continued southward through the gravel plateaux towards Ramsey, and northward across the strip of lower drift-ground between the Bride Hills and the raised beach of The Ayre, as represented in the opposite diagram. (Fig. 96).

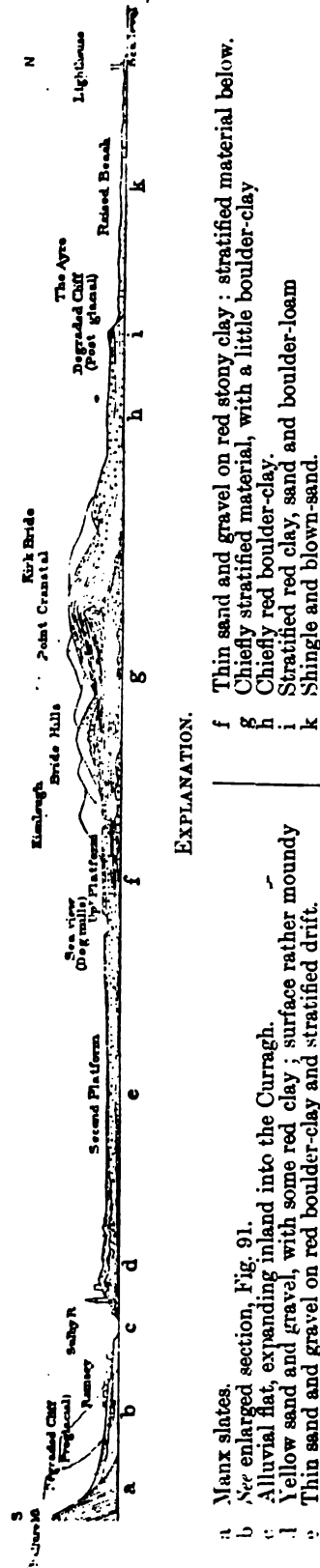
As indicated in the diagram, when traced northward beyond the mounds, the pile of stratified material is seen in part to thin out and in part to pass into red boulder-loam or clay containing many large well-glaciated erratics.

This structure is remarkably similar to that which I found in the drifts of East Yorkshire, where the Purple Boulder Clays, forming comparatively flat and low ground, pass laterally into a chain of mounds composed principally of shelly gravel and sand.¹ There is indeed in all respects a close analogy between the structure of the drift-plain of the north of the Isle of Man and that of Holderness. In both cases the pre-glacial floor of the solid rocks lies far below present sea-level, so that the existing land is due to the local heaping up of the glacial deposits; in both, again, irregular ridges of stratified material form prominent surface-features at some distance from the solid hills, with an intervening lower tract which drains inland from the coast and in which wide sheets of gravel and alluvium have collected; in both, marine detritus is abundant in some of the boulder-clays and gravels; and in both the bulk of the drift-material has been introduced from extraneous sources. In fact, the only noteworthy difference is that as the materials have been collected from tracts of widely different geological composi-

¹ "The Drifts of Flambro' Head," *Quart. Journ. Geol. Soc.*, vol. xlvii., Pl. XIII., Fig. 15.

FIG. 96. *Diagram from Ramsey to Point of Ayre, showing profile of the northern plain and mode of arrangement of Drifts.*

Scale : Horizontal, 1 inch = 1 mile ; vertical, $\frac{1}{2}$ inch = 100 feet.



EXPLANATION.

- | | | | |
|---|---|---|---|
| a | Manx slates. | f | Thin sand and gravel on red stony clay : stratified material below. |
| b | See enlarged section, Fig. 91. | g | Chiefly stratified material, with a little boulder-clay |
| c | Alluvial flat, expanding inland into the Curragh. | h | Chiefly red boulder-clay. |
| d | Yellow sand and gravel, with some red clay ; surface rather mounded | i | Stratified red clay, sand and boulder-loam |
| e | Thin sand and gravel on red boulder-clay and stratified drift. | j | Shingle and blown-sand. |

tion, the stones of the Manx drift differ widely from those of Holderness.

Another strikingly similar area is the strip of low drift-covered land which forms the southern part of the Cumberland coast, between the massif of Black Combe and the Irish Sea; and in this case the resemblance to the Manx drift-plain extends to the actual composition of the drift-material.

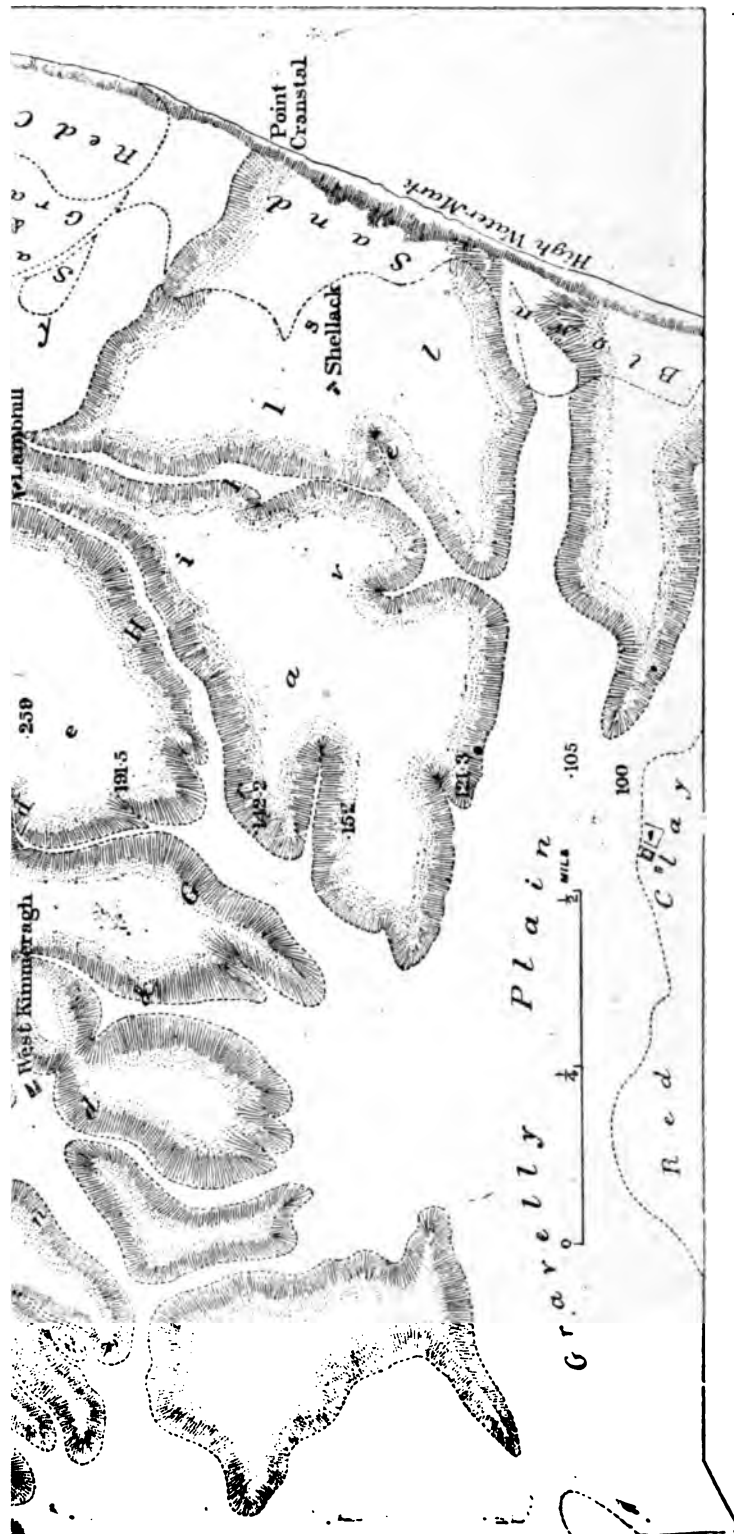
We cannot doubt that in these tracts, and in others of similar character, there has been a sameness of conditions during glacial times so that whatever explanation is adequate for the Isle of Man will be capable of wide application.

Returning to the study of the Bride Hills, we find clear evidence in their topography that neither during nor since their formation can they have been under the influence of marine action. Among the hills deep dry hollows are everywhere present, which, from their winding courses, especially in the vicinity of Kirk Bride, have often the appearance of enclosed basins and have been mistaken for "kettleholes." But when systematically traced, they are found to constitute definite valley systems, running back to the crest of the chain, and *in some cases cutting deeply across its entire breadth*, always with the principal drainage-slope descending inwards towards the gravel plateaux. The larger of these dry valleys are 80 to 120 feet in depth and from 10 to 90 or more yards wide at the floor. In one or two instances an older valley has been broached by a later hollow, but in all cases the original gradient and course of the stream is clearly indicated. To illustrate these features, a portion of the six-inch field-map on which these valleys were traced is reproduced in Fig. 97.

These dry valleys and the gravel platforms are in direct relationship. Where the larger of the old channels leave the hills we find a broad low fan of stratified material spread out upon the plain, at first of considerable thickness, but afterwards thinning off until insufficient to cover the underlying boulder-loam; and with the decrease in thickness there is a corresponding decrease in the size of the constituent pebbles. The largest of these 'over-wash plains' or gravel-deltas lies to the eastward of Jurby, at an elevation of 80 feet above O.D., and covers about 3 square miles. Though in this locality the sea has removed the greater part of the marginal hills, the direction of transport of the gravel may be traced, by its increasing roughness, to the neighbourhood of Sartfield, near Jurby, where the plain ends off among low billowy ridges of coarse gravel of extra-insular origin, containing stones up to 12 inches in diameter. Other smaller spreads of similar character lie between Kirk Andreas and the Bride Hills, as partly shown on the map (Fig. 97), and these can be followed up to the valleys whence they came.

It is clear that the same agency which scooped out the dales has spread the gravel-deltas on the plain; and it is manifestly impossible to ascribe such features to submarine action. In every particular we are confronted by the characteristics of stream-erosion.

FIG. 97. *Plan of dry valleys near Kirk Bride.*
The figures denote height above sea-level.



Thus far the explanation is simple: but the question arises, whence came running waters of sufficient magnitude? Granting even the most favourable conditions of frozen subsoil and melting snow, it is impossible that the water necessary to carve out such trenches as those around Bride, and to spread such gravels as at Jurby, could have collected on the narrow ridge. One can judge from the diminutive valleys on the northern slope of the mounds, where owing to the clayey subsoil there is still some superficial drainage, how comparatively insignificant the work of the surface-water has been since glacial times. Besides, we have to explain instances where the trenches are cut completely across the ridge, as at Lamb Hill, Thurots Cottage, and Smeale (see pp. 432-3).

This difficulty is overcome by applying Mr. Kendall's suggestion that the "great fans of gravel and sand may have been laid down by water washing freely out from the edge of the ice."¹ The crescentic ridge itself has probably formed a moraine of retrocession at the margin of the waning ice-sheet, where its front had receded, as will presently be shown, as the result of the solvent effect of the north-flowing rivers of the Island (p. 397). Streams draining from the ice-sheet into the lake-filled hollow which lay at this time between the solid hills and the ice-front trenched deeply into this moraine; and the detritus which they carried was spread out into gravelly 'overwash plains' or 'kame deltas,' partly by fluvial action and partly by the lake-waters. This seems to be the only explanation consonant with the whole of the facts; and it is at the same time borne out by the conditions actually observed at the margins of existing low-ground or 'piedmont' ice-sheets.²

Some of these phenomena are repeated on a small scale in the south of the Island, but are there less clearly developed (see details, pp. 470-2). They are all the outcome of the waning phases of the glaciation. The facts next to be described relate to the solid hill-mass of the Island, and are chiefly records of conditions during the maximum stage of the glaciation; they afford irrefutable evidence that an ice-sheet has moved across the highest summits, regardless of their contours.

Glaciated Rock-surfaces.

The presence of glacial striations on the Carboniferous Limestone near Castletown and Port St. Mary and on the slate-rocks at Cregneish was first noted by Cumming;³ and similar markings on the slates of Banks Howe north of Douglas attracted the attention of Rev. J. C. Ward,⁴ while others on Maughold Head

¹ Op. cit., p. 428.

² Consult J. C. Russell's description of the Malaspina Glacier of Alaska, in 13th Annual Rep. of U.S. Geol. Survey (1891-2), part ii. Also papers on Greenland and Spitzbergen glaciers quoted on p. 352.

³ Quart. Journ. Geol. Soc., vol. ii., p. 339, and vol. x., p. 214.

⁴ Geol. Mag., dec. ii., vol. vii., p. 6.

and South Barrule have been recorded by Mr. Kendall.¹ These are the only examples hitherto recorded; and as it happens that all are on the south-eastern or lee-side of the central hill-range, where the direction of ice-flow was influenced by local conditions, they have given rise to some misconception as to the general direction of the ice-movement across the Island. During the prosecution of the Survey about 150 new instances of these markings were observed, occurring at all elevations up to the highest summit, and in nearly all parts of the solid massif, thus affording a singularly complete body of evidence as to the character of the glaciation and the movement of the ice. The more important of these striæ have been shown on the published map, and a detailed list is given in the next chapter (p. 476), so that we need here consider only a few selected cases of especial interest.

The markings are most plentiful on the flanks of the Island and on its higher ridges, and are of rarest occurrence in the glens. In exposed places, where the general rock surface retains only its flowing outline in evidence of glaciation, fine striæ may still be sometimes found on the quartz veins, with which the slate-rocks are often seamed.² In places where the ice-flow was least likely to be influenced by the local topography, as on the higher ridges and summits, the bearing of the striæ is usually from points between N. and N.W. to points between S. and S.E. On the flanks of the hills and on the lower ground generally, the deflection from this direction is always such as, from the form of the ground, might be expected to take place in a semi-plastic mass moving across the Island from N.N.W. to S.S.E. Thus, south of Ramsey the striations swing round the north-eastern shoulder of the hills, and gradually take up a south-westerly or even a west-south-westerly course under the lee of the central chain, but swerve back to their former direction as they leave its shelter in the south-western peninsula west of Port St. Mary and on the Calf Islet. On this sheltered side of the Island, especially towards both extremities, intercrossing striæ are of frequent occurrence; in which cases the markings can usually be resolved into two sets, the one having the dominant N.N.W. to S.S.E. direction and the other showing the E.N.E. to W.S.W. deflection. These, no doubt, indicate the changing effect of local conditions upon the movement of portions of the ice-sheet at different stages of its growth. On the western side of the Island, also, there is evidence of local deflection when the ground rises steeply from the sea, as at Contrary Head where the striæ run nearly parallel to the coast. These deflected streams

¹ Op. cit., p. 405 and map. Certain of these, near Ramsey, not examined by Mr. Kendall himself, have proved to be the marks made by the sliding of screes on steep slopes, and are therefore not included in our list.

² These glaciated surfaces of quartz possess a peculiar smoothness which one soon learns to distinguish by the touch. The scratches on them are very fine, but become easily visible when rubbed with the scrapings of a lead-pencil.

FIG. 98. *Sketch-map of the Glacial phenomena of the Isle of Man.*



The arrows with ovals indicate glacial striae and the direction of ice movement.

The dotted area marks the distribution of extra-insular drift-material: the area left plain contains local drift only.

D = Dhoon Granite; F = Foxdale Granite; O = Oatland Granite; with their respective boulder-streams indicated by circlets.

The black lines indicate railways.

may have taken the form of drift-laden undercurrents, over which the upper, and perhaps driftless, part of the ice-sheet held its normal south-south-easterly course. We have already seen that the extra-insular drift material seems usually to have been confined to these lower streams, its dispersal corresponding exactly with the currents indicated by the deflected striæ.

Of individual striated surfaces one of the most interesting is that in a shallow cutting at the side of the electric tramline within 30 or 40 feet of the summit of Snaefell, the highest mountain of the Island, at an elevation of about 2,000 feet above sea-level. The striations occur on a surface of slate 40 yards distant from the summit-terminus of the line. Their direction is S. 15 E., which is transverse to the longer axis of the mountain. Other striations, having approximately the same direction, are exposed in the cuttings at slightly lower levels. In the northward prolongation of the same hill-chain, between Snaefell and North Barrule, there are further instances of high-level striæ, at altitudes ranging between 1,400 and 1,600 feet, in the shallow cols leading into the Cornah Valley; and again south of Snaefell, at 1,560 feet on Mullagh Ouyr, and at 1,340 feet on Carn Gerjoil, the direction of the striæ being always across the axis of the ridge. South of the central valley, striations similar to the above-mentioned were observed on the Slieau Whuallian range at 1,090 feet; on South Barrule at about 1,300 feet; and on the Carnanes north of Fleswick at about 800 feet.

The clearest proof that the markings were made by the flow of a mass piled up in the basin of the Irish Sea to the northward of the Island, and not by local ice, is afforded by an instance which occurs two miles N.N.W. of Snaefell at over 1,200 feet above sea-level on the rounded upland of Slieau Menagh (Monagh of the ordnance map) overlooking Sulby Glen. A crag of vein-quartz known as Creg Bedn, jutting out on the northern side of the moorland, has been rounded off and striated by the *uphill* flow of ice from the north-north-westward (Fig. 99), in which direction there is no high land. The upland is bounded on the west by the deep preglacial valley of the Sulby River; on the east and north, by a depression drained by a tributary of that stream; and is cut off from Snaefell on the south by the glen of another tributary of the Sulby. The profile of the land in the line of the striæ is shown in the accompanying diagram (Fig. 100), which, without further discussion, will render apparent the impossibility of local ice having moved in the indicated direction.

It is also noteworthy that striations sometimes occur on vertical or overhanging rock-faces. Besides examples of this character on a small scale on the Carboniferous Limestone in the south, noticed by Mr. Hewitt¹ and by Mr. Kendall, two fine instances on a larger scale were observed on the slate-rocks. One of these is on a vertical rock-face at an elevation of

¹ Proc. Liverpool Geol. Soc., vol. v. (1887-8), p. 352.

FIG. 99. Sketch-view of Creg Bedn, on the northern side of Slieau Monagh (Meanagh), near Sulby; looking west: a glaciated crag of vein-quartz, with strice pointing S. 15—25 E.; height of crag about 15 feet; width (N—S) 20 feet; length (E—W) 60 feet.

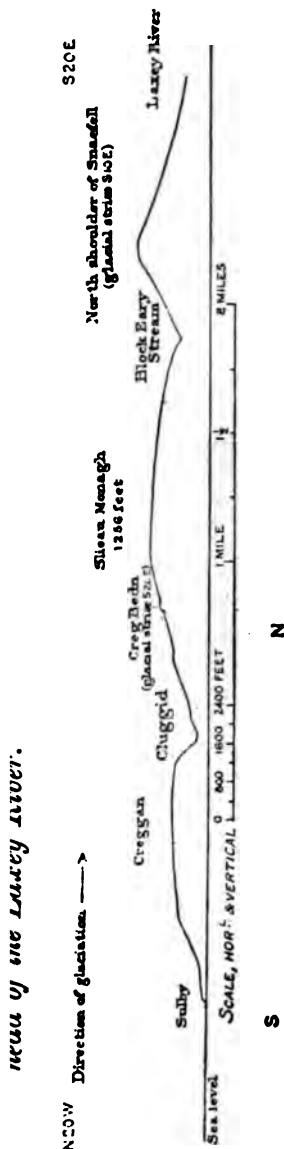


at 1,300 feet on the craggy side of North Barrule overlooking Cornah Valley, 280 yards to the westward of the fence which crosses the ridge from Park Lewellyn; the other is on the lower slopes of the eastern slope of Bradda Hill, 280 yards W. 10 S. of the farmstead of Ballalonney. In the latter instance a vertical rock-face has been undercut and fluted, the grooves being inclined at 10° towards the north, probably denoting the upward movement of ice under pressure through the low pass at Fleshwick between Bradda Hill and the Carnanes.

The only deduction which seems possible from the evidence of the striations as a whole is that the Island has been surrounded and its highest summits overwhelmed by an ice-sheet.

Dry Rock-Channels and Allied Phenomena.

Evidence of the former existence of an ice-sheet, as strong in its way as that of the striæ, is furnished by the presence of rock channels here and there among the hills, excavated by running water in positions where the land could have supplied no stream. These channels have not been observed on the main or Snaefell hill-range, but are rather numerous on the spurs which run out from it on both flanks. They usually take the form either of a shallow notch cutting the spur in a direction more or less parallel to the main range, or of a dry gulch with low craggy walls starting from the crest of the ridge. Examples of the former type may be studied on the ridge between the parishes of Onchan and Lonan, south of Laxey, at heights of 600 to 900 feet above sea level; and of the latter, on the south-western slope of

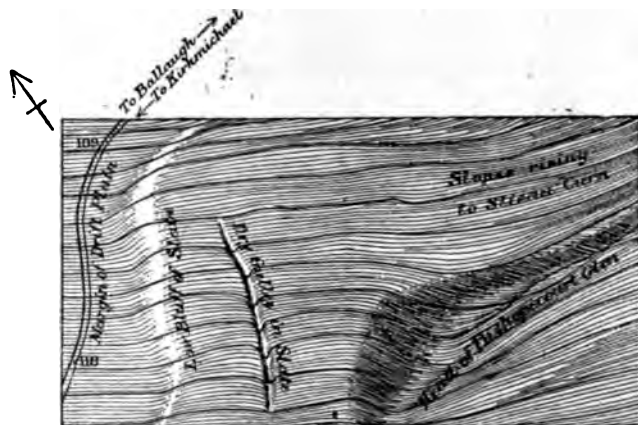


au Curn near Ballaugh, starting at an elevation of 1,058 feet. There are other instances on the westerly slope of Slieve Donard, one of which, at Ballacooley, goes parallel to the hillside not down the slope, beginning and ending without any relation to the general form of the surface. It is noteworthy

that in the vicinity of channels of this character the ground is in most cases unusually free from drift. Lower down on the same hillside, on the Bishops-court Demesne 500 yards north of Bishop's Glen, at an elevation of 200 feet above the drift-plain or 300 feet above sea-level, another singular notch is carved out in the slope, parallel to the contours, ending off indefinitely at both ends in the manner which we have attempted, not very successfully, to illustrate in the following diagram (Fig. 101).

FIG. 101. *Diagrammatic ground-plan showing dry water-course on the hillside east of Bishops Court.*

Scale : 1 inch = 3 miles. The black lines show the profile of the surface at regular intervals. The numbers give heights above sea-level on highroad.



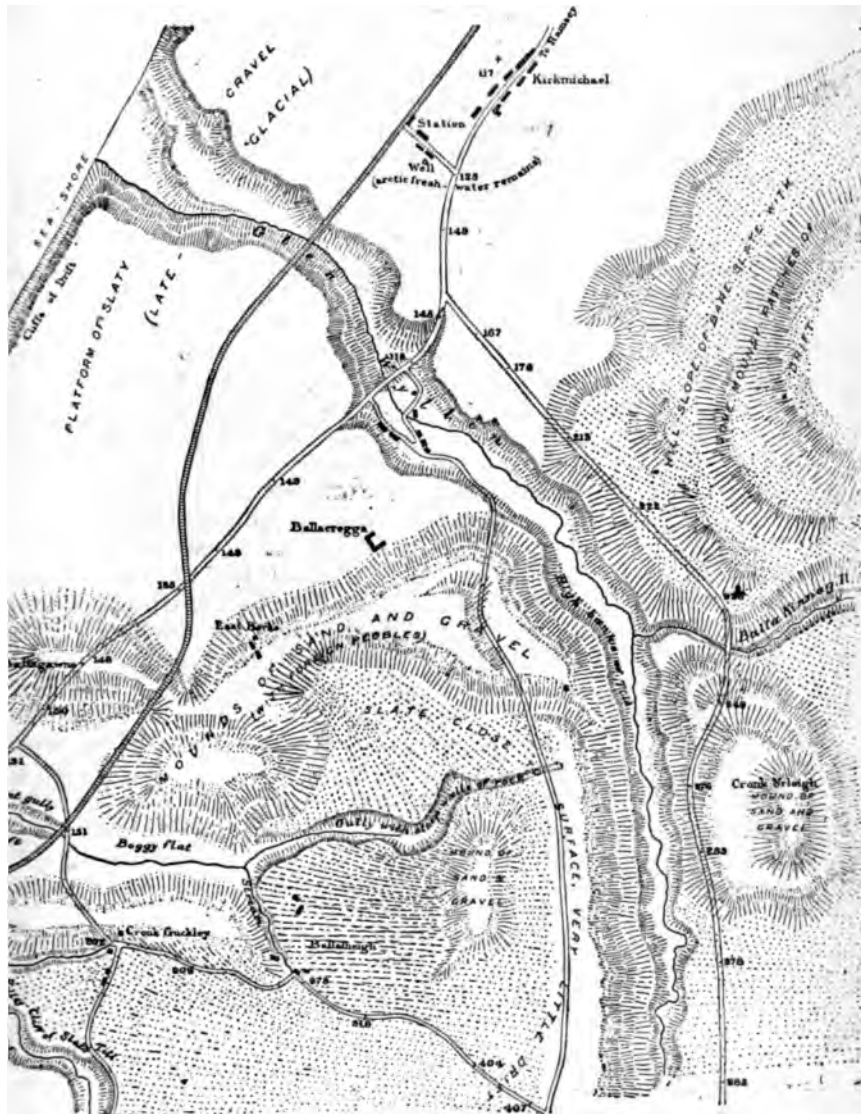
Two miles farther south, on the western side of Glen Wyllin near Kirk Michael, there is a good example of another type of dry valley. In this case the narrow steep-sided rock-ridge forming the western margin of Glen Wyllin is transversely trenched by a gully starting on the very crest, at an altitude of between 300 and 400 feet above the bottom of the Glen,¹ with the ground sinking abruptly to within 60 or 70 feet of sea-level at the head of the gully, as shown in the sketch map (Fig. 102).

The gully has been cut out of solid slate and greywacke to a depth of 50 or 60 feet, and has bold craggy walls, now somewhat shattered by weathering. To excavate this channel through such rocks must have required a strong stream of water; yet there is no catchment area whatever at the head of the gully. Nor can it be part of an old valley which has been

¹ The absence of contour-lines from the Ordnance map prevents a more precise statement of the elevations, as no opportunity was found for special levelling.

3. 102. *Sketch-map showing dry rock-valley near Ballalheigh, Kirk Michael.*

Scale ; 4 inches = 1 mile. The figures are levels in feet above O.D.



beheaded by Glen Wyllin, for the adjacent part of Glen Wyllin is clearly a preglacial valley (p. 447), while the gully has been excavated since the deposition of the drift which is piled up in mounds on both sides of it. Besides, a broad pre-glacial depression lower than the crest of the ridge extends back from Glen Wyllin to the western slopes of Slieau Freoaghane. The drift lies thick in this depression, but can never have filled it to the level of the ridge; nor is the configuration of the depression such that any glacially-dammed lake which it may have contained could have found an outlet through the gully. Nevertheless, except by postulating some temporary obliteration of the Glen Wyllin depression it seems impossible to account for the water-flow adequate for the excavation of the channel. The necessary conditions may have existed when the waning 'piedmont' ice, lingering for a time in the hollow, filled Glen Wyllin to the brim, so that a stream running partly on ice and partly on land could flow westward across it and down the channel at Ballalheigh to the outer margin of the hills at Glen Mooar. Such a stream may have had its sources in the two deep mountain-coombs between Slieau Freoaghane and Slieau Curn, which still send a strong tributary westward into Glen Wyllin almost directly in line with the dry gully on the opposite side of the valley.

A similar explanation will apply to all these dry channels. In some cases the streams by which they have been cut may have been the outflow from temporary lakelets hemmed in between the land and the ice; while other streams have been the flood-waters of the ice-sheet itself, with courses lying for the most part on the surface of the ice, but in places crossing the solid ground as it gradually emerged from the thawing sheet. These channels are not peculiar to the Isle of Man. They may be observed in almost every hilly district which the ice-sheet has overwhelmed. Many instances have recently been found by Mr. P. F. Kendall and other observers¹ in different parts of Yorkshire, and I have myself noticed good examples under the Carboniferous escarpment in the Eden Valley east of Appleby, and on the western slopes of Black Combe above Whitbeck. The abnormal dry valleys in Eastern Berwickshire described many years ago by Sir Archibald Geikie² are probably of the same character. They are common in many parts of the glaciated area of North America, where they frequently attain very large dimensions.³

That these valleys should occur in the Isle of Man at all elevations nearly down to sea-level proves the continuity of sub-aerial conditions in the area throughout the waning phases of the glaciation.

¹ P. F. Kendall, Rep. British Assoc. for 1899, p. 743; J. E. Wilson, *ibid.* for 1900, p. 755; A. Jowett and H. B. Muff, *ibid.* for 1900, p. 758.

² Memoir of Geol. Survey of Scotland. Sheet 34 (1863), pp. 51-52.

³ For references to American literature on this subject see H. Le Roy Fairchild, "Glacial History of Western New York," Geol. Mag. dec. iv., vol. iv. (1897), pp. 531-537.

The Transport of Local Boulders.

The larger plutonic masses of the Island are admirably adapted in their lithological characteristics and in their position for yielding evidence regarding the general direction of ice-movement as shown by the transport of their boulders. In this respect the Dhoon Granite, the Foxdale Granite, and the Oatland or Santon Granitite deserve our special attention. The dispersal of these boulders is roughly indicated on the sketch-map, Fig. 98, p. 360, which will serve to illustrate the following descriptions.

Dhoon Granite.—This granite has an exposure of about $\frac{1}{2}$ sq. mile on hilly ground close to the north-eastern coast-line, but it does not actually reach the coast (see pp. 142–4). Although there is lower ground to the northward of its outcrop, no boulders from it have been found in that direction, as Henslow long ago noticed (p. 332); but a broad train may be traced going southward over the upland, thus taking the course indicated by the local ice-scratches. The major part of train is intercepted by the waters of Laxey Bay, only the western fringe remaining on land.¹ Two miles farther south, however, the projection of Clay Head catches the stream again, though here they are mixed with others of extra-insular origin. Thence they may be traced, in rapidly diminishing numbers, into Douglas Bay, where they are relatively scarce. South of Douglas, though a few stones of Dhoon Granite occur in the gravels, the train is no longer recognizable. The course taken by these boulders is only explicable on the supposition that the bed of the sea to the eastward was occupied by an ice-sheet which barred the passage of the boulders in that direction and forced them coastwise southward under the lee of the hills. This conclusion is in perfect accordance with the bearing of the numerous local striæ (see map Fig. 98).

Foxdale Granite.—The boulders from this granite hold a notable place in glacial literature, since they furnished a classical and oft-discussed example of transport from lower to higher levels (for references, see ante p. 332; and Bibliography, p. 589). Cumming described the main facts with his usual accuracy, and Mr. R. H. Tiddeman supplied the true interpretation in 1872 in his well-known paper on "The evidence for the Ice-sheet in North Lancashire."² Though much has since been written on the subject, scarcely any additions have been made to the facts observed by Cumming until the present examination, which

¹ Mr. Kendall mentions (op. cit., p. 401) an altered rock in the drift near Snaefell which he thought might have come from the neighbourhood of the Dhoon Granite, but which proves to have been derived from a more immediately local source. There are no Dhoon boulders in the tract referred to.

² Quart. Journ. Geol. Soc., vol. xxviii., p. 488.

has thrown fresh light upon the dispersal of these boulders, while fully confirming the theoretical conclusions of Messrs. Tiddeman, Kendall, and others.

The granite is exposed on a col of the main watershed south of the central valley, at an elevation of 600 to 700 feet¹ above sea-level (see p. 165). The deep trench-like valley of Foxdale drains northward from shallow depressions at the margin of the granite; and from the same boggy ground spring the Santon River and the Silverburn, which flow southward in broad open valleys with a much more gradual descent. To the eastward the ground rises gently towards Archallagan, and to the westward mounts steeply for 500 feet into the truncated end of the ridge of South Barrule, and then more gently to the summit of that mountain, 1,585 feet above sea-level.

Boulders of the granite are scattered sparsely on this mountain up to its very summit, attaining a maximum elevation of about 900 feet above their source within 1½ miles of the granite outcrop. It seems hitherto to have been taken for granted that they have travelled from the outcrop directly up the nearest slope, but this does not appear to have been the case. They have probably travelled by a more circuitous route, under less simple conditions than are at first sight suggested, though not essentially different.

Participating in the dominant ice-movement, the main stream of boulders has passed southward down the parallel valleys of the Silverburn and Santon, spreading out slightly towards the east, so that stragglers have gone over a low water-parting into a more easterly depression which drains to the sea at Port Soderick. On the shore at the last-mentioned place may be found an occasional block of the granite, and westward they become more plentiful, so that between Santon Head and Port St. Mary they are often rather abundant between tide marks in sheltered places. The greater part of this southerly boulder-train has, however, been deflected westward as it left the hills, by the south-westerly lee-side current of ice, and has not reached the coast. Consequently the boulders are strewn in greatest profusion over the parish of Malew between the outcrop of the granite and the village of Ballasalla, and over all the ground in Arbory, the next parish to the westward, between the mountains and the west-going main-road through Colby. To the westward of Colby, boulders of the granite, along with other local and a few foreign erratics, are scattered here and there over the south-western peninsula of the Island, and also on the Calf of Man, but no definite train is distinguishable. As the rock-striae indicate that a tongue of the main ice, from the westward of the Island, has pressed in south-south-eastward through the gap at Fleshwick, and has also overwhelmed Bradda Head, the obliteration of the local current in this quarter is perfectly explained.

¹ Mr. Kendall states, on the authority of the Director of the Ordnance Survey, that "Granite Mountain" is 657 feet above O.D. : op. cit. p. 401.

Considering the small extent of the granite outcrop, the number of boulders which it has sent off is remarkable. Within the main train, over an area of 6 square miles the fences and farm buildings contain little other material, and the moorland south of the granite is strewn thick with blocks. The boulders lie for the most part at or near the surface; and as apparently only a small number have been carried beyond the present coast-line we probably still see a large proportion of the blocks originally transported. Their removal must, of course, to some extent, have lowered the level of the outcrop; but, judging from the shape of the ground, the lowering does not appear, after all, to have been great. An estimate might possibly be made of the total number of the boulders, which would afford the basis for an approximate calculation of the thickness of rock removed.

The high-level boulders on South Barrule and Cronk ny Arrey Lhaa, lying to the westward and west-south-westward of the granite, cannot have been transported in the stream just described. As Cumming pointed out in 1846¹, they lie on the north-western as well as on the south-eastern side of South Barrule; and he remarked on the difficulty of accounting for this distribution on the opposite sides of the mountain by the then prevalent theory of floating ice and marine current action. Ward and Kendall, likewise, have drawn attention to the anomalous position of these blocks on the north-western slopes of the hill-range. But the difficulty disappears when the ground to the north and north-westward of the granite outcrop is closely examined, as it is then found that a small train has been given off in this direction also.

This minor train seems to have gone northward down Foxdale for about a mile, hugging the western slope of the valley, and has then turned westward out of the Foxdale depression into the high-lying hollow between South Barrule and Slieau Whuallian in which lies the watershed between Foxdale and Glen Rushen (see p. 10). On the moorland forming the south-eastern side of this hollow from Doarlsh Head to Ballavell the boulders are abundant, rising steadily to higher levels; the majority of these lie below the old highroad, which is from 900 to 1,000 feet above O.D., but there are numerous examples above the road, scattered over the western slope of South Barrule up to the summit. They are also scattered, in diminished numbers, around the head of Glen Rushen at about 1,200 feet above O.D. on Cronk Fedjag, and at over 1,400 feet on Cronk ny Arrey Lhaa; and stragglers have apparently been carried southward over the ridge and thus into the territory of the previously described main stream on the south-eastern side of the mountains. The striated surfaces of the area fully confirm the evidence of the boulder-trains. On the granite outcrop and on the north-eastern crest of the ridge of South Barrule, the striations are in the direction of the principal

¹ Quart. Journ. Geol. Soc., vol. ii., p. 341.

ice-flow, viz., N.N.W. to S.S.E.; and the same is the case on the southern spur of Cronk Feijag; while on a well-glaciated surface on the north-west slope of South Barrule, at the small slate trials south of the highroad, the striæ bear nearly N.E. to S.W.

The curious westerly uphill divergence of the north-moving train from its apparently inevitable course down Foxdale was doubtless caused by the lobe of foreign ice which crossed the mouth of the valley on its way up the Archallagan slope as previously described (p. 350). With this intruding mass to the north and east, the local ice which had previously accumulated at the head of the valley could find no passage along the ordinary drainage channel, and was pent back into the lateral depression and forced up westward along its slope. At a later stage, the ice-sheet in the sea-basin to the north-westward was piled high enough to flow across the summit-ridges of Slieau Whuallian (p. 458) and South Barrule, and across the local ice which lay between them; and then the local stream was gradually frayed out and dragged, with its contents, southward across the hill-chain. By this route have the boulders reached their present position on the mountain; and consequently they are absent or at any rate extremely rare (the ground is partly obscured by young trees and gorse) on its eastern slope immediately overlooking the outcrop of the granite (see map, Fig. 98). From what has been elsewhere noted (p. 352) it is clear that the bluff character of this slope would in itself have deterred the passage of the boulders even had the general movement of the ice been in its direction.

As to the question whether the changes of direction may not represent separate and distinct stages of the Glacial Period, it may be pointed out that the facts are all consonant with the other evidence, in leading to the conclusion that from the beginning of the accumulation of local ice on the uplands to the overwhelming of the Island by an extraneous ice-sheet, and to its reappearance on the shrinkage of the ice from its slopes, there has been a progressive development of conditions, without marked interruption. Changes of direction of flow must in many localities necessarily have accompanied the growth and wane of the ice, and these seem sufficient to explain all the observed phenomena.

The Oatland Granitite.—The small boss of granitite with its interesting marginal rim of basic rock which is exposed at Oatland, in the parish of Santon (p. 320), has sent a fan-shaped stream of blocks southward and south-westward, as shown in Fig. 98, in a direction corresponding with the local striæ. The south-eastern fringe of the principal Foxdale boulder-train overlaps upon this stream in such a manner as to suggest that the two may have lain at different horizons in the ice; and this is the more likely since the parent-rock at Oatland is 400 feet lower than at Foxdale. In other respects the evidence of the

Oatland boulders is a repetition of that of the Dhoon boulders. (For further details, see p. 469.)

Other Local Boulders.—A dyke-rock of peculiar character outcropping at Ballapaddag Farm, near Ballabunt 3 miles west of Douglas, at an elevation of 300 feet above sea-level, has sent boulders south-westward up the slope of Richmond Hill, and southward around its shoulder. These boulders rise in half a mile 200 feet above the parent-mass, and avoid lower ground to the eastward.

In the sister valleys of the Baldwin and the Glass in the interior, south of Snaefell and Beinn y Phott, the local drift contains boulders of peculiar actinolitic greenstone and of quartz-veined grit, which are abundant southward up to the union of the valleys. But while the drainage depression turns sharply south-eastward from this point, the boulders, re-inforced by others from a pale micro-granite dyke, rise southward up the slopes out of the valley, indifferent to the local contours; and crossing the dividing ridge, pass down into the main central valley between Crosby and Union Mills.

In every case there seems no escape from the assumption that the dispersal of the boulders has been effected by an ice-sheet which occupied the surrounding sea basin and covered the Island. In no instance is the agency of floating ice adequate to explain their distribution.

Late-Glacial Flood-Gravels.

The later stages of the Glacial Period in the Isle of Man are marked by a set of phenomena which carry on the history of the episode to its close, passing without a break, insensibly into the Post-glacial or Sub-recent stages.

The state of affairs which accompanied the disappearance of the ice-sheet from the flanks of the hills is, as previously explained, partly illustrated by the dry rock-valleys and by the crescentic drift-ridge of the Bride Hills. It is further indicated by the presence of patches of re-arranged drift, sometimes stratified and sometimes not, overlying the till in places on the hill-slopes where stream-action under existing conditions would be impossible. At the lower levels this re-arranged material sometimes forms terraces, which probably mark the sites of small fresh-water lakes temporarily held in between the ice and the land. One such lake seems to have lain in the central valley between Peel and Greeba; and another in the same valley between Crosby and Douglas. In the south of the Island the low ground between Port Erin and Castletown was probably occupied by a similar lake, which seems to have received a river from the westward ice-sheet through the gap in the hills at Fleshwick, as indicated by the gravel delta spreading out between Bradda and Kentraugh.

In such basins the alluvial fans of local material at the mouths of the little hill streams are remarkably large and out of proportion to the drainage areas; and most of these seem to have been deposited while the lakes still existed. (See details, pp. 437-40, *et seq.*)

These re-arranged drifts constitute the chief part of the deposits classed by Cumming as "*Diluvium*," to distinguish them on the one hand from his "*Boulder Clay*," and on the other from his "*Drift-Gravel*" divisions.¹

It is in the north of the Island, however, that these phenomena are best displayed. There, in the great hollow formed, as subsequently explained (p. 397), between the retreating ice-front and the Slate hills, we have on the northern side the broad gravel platforms or overwash-plains already described, representing the extra-insular drainage from the ice-sheet, and on the southern side great flats and spits of slaty gravel running out from the mouths of the larger valleys into the Curragh, which show how powerful were the floods from the land at this period. At the mouths of Glen Auldyn and Sulby Glen these land-stream deltas are separated from the northerly drift-gravel platforms by lower tracts of alluvium and peat-bog; but the fan from Glen Dhoo, at the western edge of the hollow, has coalesced along its northern margin with a low-level drift-gravel platform, and the two can only be distinguished by their composition (a dotted line on the published map marking approximately the limits of the slaty gravel). To this period of rapid erosion we may likewise assign the excavation of the craggy ravines seen here and there in the upper reaches of the valleys, where the swollen streams in clearing out the glacial *débris* from their pre-glacial channels have temporarily lost their way and bitten into the solid rock (p. 449).

In its earlier stage the waters of the lake which filled the northern depression seem to have stood at from 80 to 100 feet above present sea-level, though probably subject to occasional or seasonal fluctuations of wide extent. To this time must be assigned the construction of the great terrace at Jurby and those fringing the Bride Hills east of Andreas, by material derived in part directly from the waning ice-sheet, and in part from the erosion of the valley system of the Bride Hills. The discharge of the lake at this stage may have been round the north-eastern shoulder of the mountains at Ramsey, and thence southward through the depression of Port e Myllin and Port Mooar and along the south-eastern flank of the Island, which may explain the general though slight fall of the gravel flats towards the east. With the further retreat of the ice-sheet a pass would be opened northward through the drift-ridge at Lagagh Mooar between Knock-e-Dooney and Knock-e-nean, where the morainic chain is broken for a space; but whether there was ever any discharge in this direction can scarcely now be established, as the post-

¹ Quart. Journ. Geol. Soc., vol. ii., p. 341.

glacial encroachment of the sea has carried away the tract which might have yielded the requisite evidence.

The lake was subsequently drained down to between 40 and 50 feet above present sea-level. At this level it remained for some time, carving out a well-defined margin in the incoherent drift-material south and east of Jurby and producing a lower terrace from the wash brought down into it by small streams whose trenches, now mainly dry, furrow the higher platform (p. 434). By this time the ice-front seems to have withdrawn beyond the limits of the Island, and the waters from the lake found a passage northward through the channel known as The Lhen, which forms the most striking feature in the topography of the northern plain (see map, Pl. I.).

The later history of this curious valley properly belongs to Post-glacial times, and should be left over for consideration in the next chapter; but the dividing line between Late-glacial and Post-glacial is so ill-defined that no excuse is needed for carrying on its record here. From its commencement at the northern margin of the Curragh to its mouth the valley is over four miles long, cutting in graceful curves through the high gravel-plateau and the morainic ridge till it reaches the sea at the north-western angle of the Island, three-quarters of a mile S.W. of Blue Point. It is clearly of fluvial origin, with banks 30 to 50 feet high and a singularly wide and level floor, now mostly occupied by boggy alluvium, from 100 to 300 yards across. There is some reason to believe that it affords an example of reversed drainage, having probably been originally one of the valleys by which the waters from the ice-front were carried inwards to the lake-hollow, as the principal channels tributary to it on both banks trend southward, and at their confluence with it make an acute angle on the present down-stream side; and moreover its floor is three times wider in the southern or present up-stream than in the northern or present down-stream part of its course, although the character of the material in which it is excavated is the same throughout. Its south-flowing stream ceased, however, with the disappearance of the ice; and the abandoned bed served afterwards as the main channel of the northward-pouring waters of the lake-filled basin which on the opposite side was fed by the copious mountain-streams from Sulby Glen and Glen Dhoo. Lastly, as the climate became drier, these sustaining mountain-streams shrank until they were no longer able to surmount the barrier of their own old flood-gravels; and were thereby dammed out of the hollow and diverted, the Sulby River into an independent eastern and the Glen Dhoo stream into an independent western course to the sea. Thus once more did the Lhen lose its river; and its broad channel became a peat-bog until about 150 years ago, when an artificial trench was dug along it to carry off some of the lowland drainage.

Thus the whole history of the Curragh basin shows a continuity of land and fresh-water conditions from the Glacial Period to the present time.

In a little basin lying between the north-western flank of the mountains at Bishops Court and the drift-mounds of Orrisdale, some of the phenomena of the Curragh are repeated on a smaller scale. At Kirk Michael, about a mile farther south, there is a larger delta-platform of slaty gravel, lying around the mouth of Glen Wyllin, between 100 and 150 feet above sea-level, which has probably been likewise bounded by drift-mounds to the westward until broken into by the encroachment of the sea.

That these delta-gravels were deposited on land and not in the sea was clearly proved at this place. A well sunk in 1894 at a new house 50 yards south-east of Kirk Michael Railway-Station, at an elevation of about 120 feet above O.D., passed through a seam of peaty material at a depth of 15 feet from the surface, overlain and underlain by the slaty gravel. Some of this peaty bed, sent to Mr. Jas. Bennie (of the Scottish Survey) for treatment, yielded, under his skilled manipulation, the remains of the little Arctic fresh-water crustacean *Lepidurus* (*Apus*) *glacialis*, which lives now in icy pools around the glaciers of Norway and Spitzbergen. This organism had previously been detected by Mr. Bennie in fresh-water deposits of Late-glacial age in three localities in Scotland, viz.: Hailes, Corstorphine, and Dronachy,¹ but had not hitherto been found so far south in the British Isles. Among other remains associated with this crustacean were the leaves and seeds of plants, including an Arctic willow (*Salix herbacea*) and an Arctic sedge.² I am indebted to my colleague, Mr. Clement Reid, for the following list, based on the material prepared by Mr. J. Bennie:—

Fossils from peat and silt in platform-gravel near Kirk Michael Station.

Flowering Plants.	Mosses. ⁴
<i>Ranunculus aquatilis</i> , <i>L.</i>	<i>Philonotis fontana</i> , <i>L.</i>
<i>Viola</i> (palustris ?), <i>L.</i>	<i>Hypnum cuspidatum</i> , <i>L.</i>
<i>Potentilla Comarum</i> , <i>Nestl.</i>	<i>Pogonatum alpinum</i> ? <i>L.</i>
<i>Hippuris vulgaris</i> , <i>L.</i>	<i>Polytrichum juniperinum</i> , <i>Willd.</i>
<i>Menyanthes trifoliata</i> , <i>L.</i>	<i>Grimonia</i> sp.
<i>Salix herbacea</i> , <i>L.</i>	
<i>Potamogeton</i> sp.	<i>Lepidurus</i> (<i>Apus</i>) <i>glacialis</i> , <i>Kroeyer.</i>
<i>Eleocharis palustris</i> , <i>R. Br.</i>	<i>Daphne.</i>
<i>Carex alpina</i> , <i>Sw.</i> ³	Insect remains (undetermined).
<i>Carex (glauca)</i> ?	

Regarding the conditions under which this bed was accumulated Mr. Reid notes "the peat is not lacustrine, but was evidently formed in a slack. Three of the plants (*Ranunculus aquatilis*, *Hippuris vulgaris*, and *Potamogeton*) though perhaps most often aquatic, have all bog varieties. The others point definitely to a spongy bog."

¹ See Annual Report of the Director-General of Geol. Survey for 1894, p. 287; and J. Bennie, *Annals of Scottish Nat. Science* for Jan. 1895, p. 55.

² Ann. Rep. of the Geol. Survey for 1895, p. 13.

³ Determined by Mr. C. B. Clarke.

⁴ Determined by Mr. W. Mitten, who remarks, "nothing to denote difference of climate."

The same arctic freshwater fauna has since been found in a small hollow on the plateau of slaty gravel at the mouth of Glen Dhoo, bordering the western Curragh one mile east of Ballaugh, at an altitude of 70 feet above sea level. At this place the generally plane surface of the gravel is broken by a group of nine or ten curious shallow depressions, the larger occupied by water-pools, the smaller dry, ranging from 20 yards or less to 150 yards in diameter. These pits have no outlet and are not connected with the surface-drainage. They apparently date back to the time of the deposition of the gravel, and may perhaps represent the melting out of buried masses of ice, in which case they might be considered small 'kettle-holes'; or they may only mark eddies where the stream-waters poured into the lake. Though not altogether confined to this one locality, they are nowhere else so clearly developed (see p. 438). Most of them contain more or less alluvium, and those which still hold water-pools must have been continuously in this condition since their formation. Their freshwater deposits may therefore range from Late-glacial times to the present day. Early in the nineteenth century large numbers of bones of Irish elk were obtained from marl-pits in these hollows (p. 382); and with the object of investigating the conditions under which these remains occurred, a British Association Research Committee was appointed in 1896 to co-operate with a local committee which had previously been formed; and under their joint auspices excavations were made in the hollow known as Loughan Ruy, on the farm of Ballaterson, 950 yards E.N.E. of Ballaugh Church. The following extracts from the reports of this Committee give the results of the investigation¹ :—

Section at Loughan-ruy, Ballaterson, Ballaugh.

	Thickness of bed. Ft. in.
A. Peat - - - - -	1 6
B. Sand, yellow - - - - -	1 0
C. Sandy silt, grey (with <i>Salix herbacea</i> and <i>Lepidurus (Apus) glacialis</i>) -	2 6
D. Loamy peat - - - - -	0 8
E. Gravel - - - - -	1 0
F. Marl ('Chara Marl') - - - - -	0 4
G. Sharp sand and gravel - - - - -	0 6 and more.
Depth excavated - - - - -	7 6

The following species of plants and animals were obtained on washing samples of the deposits :—

Bed A.

Ranunculus Flammula, L.	Hydrocotyle vulgaris, L.
Potentilla Tormentilla, L.	Potamogeton, sp.

Also caddis cases and eggs of insects.

The plants are all common Isle of Man species.

¹ See Reports by the Secretary, Mr. P. M. C. Kermode, in Repts. British Assoc. for 1897, p. 346, and for 1899, p. 376. The plants were determined and reported upon by Mr. C. Reid from material prepared by Mr. J. Bennie.

Bed C.

<i>Ranunculus aquatilis</i> , L.	Moss.
<i>Poterium officinale</i> , Hook.	
<i>Salix herbacea</i> , L.	<i>Lepidurus</i> (Apus) <i>glacialis</i> , Kroy.
<i>Carex</i> , sp.	
<i>Schoenus</i> ?	Daphne (winter eggs).

Numerous leaves of the dwarf Arctic willow *Salix herbacea* and fragments of the Arctic crustacean *Lepidurus glacialis*, neither of them now living in the Isle of Man, point to climatic conditions considerably more severe than those now holding in the district.

Bed D.

<i>Ranunculus aquatilis</i> , L.	<i>Potamogeton crispus</i> , L.
" <i>Flammula</i> , L.	<i>Carex</i> .
" <i>repens</i> , L.	<i>Chara</i> .
<i>Littorella lacustris</i> , L.	Beetle (elytron).

The plants are widely distributed species still living in the Isle of Man. *Littorella* is usually northern.

Bed F.

<i>Ranunculus aquatilis</i> , L.	<i>Carex</i> .
" <i>Flammula</i> , L.	<i>Chara</i> , 2 sp.
" <i>repens</i> , L.	
<i>Littorella lacustris</i> , L.	<i>Lepidurus glacialis</i> , Kroy.
<i>Empetrum nigrum</i> , L.	(A single specimen.)
<i>Potamogeton natans</i> , L.	
" sp.	Insect remains.

This marl thus far has yielded nothing to indicate the climatic conditions except the single specimen of *Lepidurus glacialis* which, as Mr. Reid points out, may possibly have been introduced from the higher bed, where it is abundant. The absence of arboreal vegetation seems, however, to indicate a severe climate.

In a later exploration of the same site (described by Mr. Kermode in Rep. British Assoc. for 1900, p. 349) a trench was cut in a deeper part of the basin, a few yards north-west of the section above described, and showed a considerable thickening of all the beds, besides yielding traces of the elk both in the silt and in the marl. The following is quoted from Mr. Kermode's report:—

'In the peat [A], which extended from the surface to a depth of 3 feet, were several pieces of timber, the largest being about 15 inches diameter at the root: this bed rested upon silt [C], which extended to a further depth of 7 feet. It varied slightly in different parts, here more sandy, there more loamy, but was really all one bed, the bottom of which consisted chiefly of small flat water-worn stones. At a depth in this bed of 6 feet, that is to say, about 9 feet from the surface, was a layer of leaves about half an inch thick.

In this layer, on the south-east side of the trench, about 3 yards from its south-west end, was found a fragment of antler, thickly covered with the blue phosphate which appears to be confined to this leaf-deposit. All around it were minute decayed fragments of bone or antler.

Three or four yards away, at a depth of 10 feet from the surface, being about 3 inches from the white marl bed, but distinctly in the silt, was another fragment of antler: this was in the north west side of the trench, and about a yard from its south-west end.

The marl [F] was struck at a depth of 10 feet to 10 feet 3 inches; and at a point from 9 to 12 inches within it, that is to say about 11 feet below the present surface, there was still another antler fragment, some 3 yards further south-east than the last, in the south-west end of the trench. Immediately below this the marl was bluish black, exactly as it was round the head of the skeleton found near St. John's (Close-y-Garey). This darkened marl was from 9 to 10 inches thick, and extended over an area from the south-

west end of the trench of about 3 feet square. All through it were crumbs of decayed bones, doubtless Irish Elk.'

'The following paragraph was added to our last [1899] report after it was in type, and the bone in question exhibited at our Dover meeting, but by some accident it was omitted from the report as published, so we insert it here. 'At a depth of about nine feet below the surface at the bottom of the silt (Bed C of our first report), and just above the white Chara-marl, were found two fragments of bone, which were forwarded to our Chairman [Prof. W. Boyd Dawkins], who has identified one as the scapula of *Bos longifrons*, and in a letter to the Secretary adds: "This establishes the presence in the island of an animal which was domesticated and introduced into the British Isles in the Neolithic age. It proves that this deposit in which it occurs is not earlier than the Neolithic age."' [See foot-note¹.]

In the above excavations only fragmentary relics of the Irish Elk were discovered; but the study of the old records leaves no doubt that the fine specimens previously obtained from this place were found in the Chara-marl, F, which was much thicker towards the middle of the hollow where the old pit was worked. In later researches carried on by the same Committee at another locality, as presently to be described, a good skeleton of the elk was unearthed. There has been much discussion respecting the age of the elk-bearing deposits in Ireland and their exact relation to the Glacial Period; and as the Irish sections appear to be closely analogous to those of the Isle of Man, the discovery of arctic remains in the above section, in a bed overlying that which yielded the elk, is of wide interest.

We may therefore profitably devote a few pages to the discussion of the previous records of the occurrence of *Cervus giganteus* in the Isle of Man, and to their comparison with the results of the recent investigations.

***Cervus giganteus* in the Isle of Man.**

Since the discovery of the first nearly complete skeleton of the Irish Elk in a marl-pit near Ballaugh early in the present century, the Isle of Man has been recognised in geological literature as one of the typical localities for the occurrence of this animal. Curiously enough this is the only Pleistocene vertebrate yet definitely proved to have existed in the Island, though a drifted fragment of elephant's tusk has been found at Jurby (p. 423) and another fragment supposed to be a cetacean rib is mentioned by Cumming² as having been obtained from the drift at Douglas, and there are doubtful records of the red

¹ With regard to the last quoted paragraph, however, we may be permitted to state that it is doubtful whether the bone in question should be assigned to *Bos longifrons*. Mr. E. T. Newton, of the Palæontological Department of the Survey, has examined the specimen since the report was written, and is of opinion that it more probably belongs to an immature individual of *Cervus giganteus*; and the presence of fragments of antlers in the same bed lends support to this opinion. At any rate the evidence is at present insufficient to justify the conclusion drawn by Prof. Dawkins as to the age of the deposit.

² Isle of Man, p. 360.

deer and horse (p. 384) and of *Bos longifrons* (p. 377). The elk-remains have been found in four or five localities only, apparently always in the smaller boggy basins, and never in the broad Curragh although much draining and peat-cutting has been done there.

The earliest reference to these remains which has come under our notice is by J. Feltham in his "Tour through the Isle of Man," published in 1798, where he mentions (p. 205) that bones of "elks, or seghs," found near St. John's, were shown to him by Rev. Mr. Corlett. "The horns measure 9 feet from tip to tip, and from other bones, conjecture is warranted to suppose the animal must have been 17 feet high." Woods (1811) also records this specimen (p. 13). It must have been an earlier find than the first one mentioned by Mr. P. M. C. Kermode in his recent account of the local history of the subject, which is of a head and antlers "found in a marl pit in the parish of Ballaugh in June, 1815." The latter discovery may be the one mentioned by Train in his "History of the Isle of Man" (1845), who stated, probably incorrectly, however, that the specimen was from "the extensive morass called the Curragh." "Another discovery—the date not recorded—was that of a skeleton found in a marl pit on Ballaterson Mooar, Ballaugh,"¹ the head and antlers of which are now in King William's College at Castletown.

The first scientific reference to these elk-remains appeared in a letter on Phosphate of Iron, by J. Murray, dated May 19th, 1818, which was published in "Annals of Philosophy" for that year (vol. xii., p. 147). Mr. Murray described the occurrence of bones of elk in a bed of shell-marl overlain by peat on the farm of 'Ballatesin,' Ballaugh, and of a blue earthy mineral, supposed to be phosphate of iron, on the horns and in the peat-earth. He also stated that chips of flint were found in the marl, a circumstance not mentioned by any later observer.

The more celebrated discovery was made in the adjacent hollow of Loughan Ruy in 1819, of which Henslow gives the following account²:—"Whilst I was in the island, in August, 1819, two heads with the branches and a vast number of bones were dug up in the finest preservation. An ingenious blacksmith in the neighbourhood, taking the skeleton of a horse for his model, has contrived to put together these bones with great accuracy, and form a skeleton in which the only parts wanting are the half of one hoof and the end bones of the tail. It has a most magnificent appearance, stands 6 feet 6 inches to the top of the back, and 13 feet to the top of the horns." The 'ingenious blacksmith' seems however to have used his equine model rather freely, making up from it the parts which were wanting in the elk skeleton.³

¹ P. M. C. Kermode. *Yn Lioar Manninagh*, vol. iii., pt. viii., p. 395.

² *Trans. Geol. Soc.*, vol. v. (1821), p. 502, footnote. Short notices of this discovery were also given anonymously in the *Edinburgh Philosophical Journal* for 1821, vol. v., p. 227, and for 1823, vol. viii., p. 198.

³ Kermode, *op. cit.*, p. 397.

When completed, this specimen was exhibited for payment to Lewis on behalf of himself and James Taubman, the tenant of the field, but was then claimed by the Duke of Athol as Lord of the Manor; and, after a law suit, an agreement was made by which the elk came into the Duke's possession, and was by him presented to the Museum of the University of Edinburgh.¹ This skeleton was figured by Cuvier in his "*Ossemens Fossiles*," vol. iv., pl. 8, and p. 82), from an engraving transmitted to him by Prof. Jamieson.² Regarding this figure Dr. Traquair writes (in a letter to Mr. Kermodé quoted in a footnote in *Yn Lioar Manninagh*, vol. iii., pl. viii., p. 397), "I found when I took it to the Museum that the pelvis in the skeleton was that of a common horse, which I accordingly had replaced by the pelvis of a real Irish elk from Ireland. . . . This (Cuvier's) figure represents the skeleton exactly as it was before I had it altered by replacing the horse pelvis with one of the Irish elk, and by giving a proper curve to the vertebral column, which was absolutely straight in the dorsal and lumbar regions." Dr. Kermodé then gave a description of the section in which the bones were found, which may be tabulated as follows:—

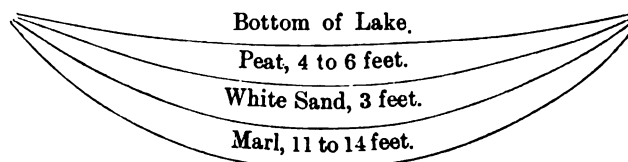
At the top; 'turf and vegetating matter' - -	1 or 2 feet.
'A kind of peat, composed of rotten leaves and small branches closely matted together, mixed with sprinkles of sand, and containing a vast number of the exuviae of beetles, bees and their nests, crushed together with seed-vessels, rotten, but having their external coating well preserved. . . . In general the hard wings are the only parts of the beetles which are preserved, and these are in appearance as fresh as on a living insect. Dr. Leach was enabled to identify a few with species at present existing in England.'	About 1½ feet.
'A bed of sand of a light colour' - -	6 feet.
The marl white or greyish, and the fracture resembles that of a highly decomposed peat, converted to a loose earthy calcareous substance, and through it are dispersed in every direction the traces of small branches and roots, which partake of the character of the mass. When dry it does not become indurated, but is easily reduced to a powder between the fingers. Native phosphate of iron, in an earthy and pulverulent state, is sometimes found in contact with the bones.'	No thickness stated.

The section was again described a few years later by H. R. Oswald, in a letter dated May 29th, 1824, addressed to the Bishop of the Island, which was printed as an appendix to a paper on the discovery of the elk by Dr. S. Hibbert in the "*Edinburgh Journal of Science*," vol. iii. (1825), p. 28. Oswald gives a rough

¹ Kermodé, op. cit., p. 398, and *Yn Lioar*, vol. i., No. 1, pp. 23-4.

² Cumming, *Isle of Man*, p. 214.

diagrammatic section across the basin to show the thinning away of the deposits on both sides, of which the following is a copy. The differences between this section and that of Henslow on the one hand, and that exposed in the recent excavation by the British Association Committee on the other, are readily explained by this diagram.



Oswald seems to have been the only observer who had the opportunity to examine the thicker portion of the deposits. He states: "The superficial stratum is peat of excellent quality, light and fibrous, and containing a few trees of bog-timber. It is 6 feet thick in the middle part of the morass, but passes out thin, into a black peaty turf towards the margin." [Compare Bed A. of section on p. 375.] "Between it and the marl, a layer of fine bluish-white earthy sand is interposed, from 2 to 3 feet in thickness." [Compare Beds B, C, D of section on page 375.] "The marl lies at a depth of from 7 to 10 feet at the middle parts of the pit, but, like the peat, becomes thin at the margin, and passes out when within a foot and a half of the black till which forms the surface crust. Nearly one-half of this deposit has been worked during dry seasons, but I have never seen the pit completely drained of its water. According to the calculation of the workmen, the bed of marl in the middle parts of it is from 11 to 14 feet thick, independent of the layers of turf and sand which I have noticed. When the workmen penetrate at any time through the marl the pit is suddenly inundated by water springing up from below, from the sand and gravel which form the subsoil. This marl is highly fibrous, and somewhat laminar in its structure, and when dry is as light and nearly as white as chalk. The shells are delineated white upon a darker ground, and are seen by separating the fibrous layers, but are seldom, if ever, found in their original state. I question much whether shells exist in all parts of the basin, certainly not at its margin." [From this it appears that the conspicuous absence of shells in the marl of the recently-opened section, and from that described by Henslow, is characteristic only of the margin of the hollow.] "In this basin vast quantities of bones of the large species of elk are found. The workmen have constantly met with them since the first opening of the pit, and therefore conclude that an incalculable number still remains. These bones occur at all depths of the marl. At and towards the surface of it the bones, like the shells, are merely delineations of what they once were, with little or no difference in consistence from the mass in which they are contained, and therefore will not bear

handling; in the bed of sand above the marl all vestiges of them disappear. The deeper these elks are in the marl the more fresh and perfect they seem, and near the bottom of the bed complete heads are found. They sometimes, though very seldom, are observed imbedded partially in the gravel below. Those in the marl are generally charged with calcareous matter, yet I have frequently seen the thick part of the stem of the horns so unchanged as to admit of being worked. *The bog-timber is in this instance solely confined to the peat on the surface.* [Italics not the author's.]

Oswald next describes the conditions under which the Edinburgh specimen was obtained and put together. He then notices other "basins of white marl in which no shells now appear. These lie lower down the plain, nearer the deposits of common clay-marl" [glacial clays]. "In one of these basins, distant upwards of a quarter of a mile from that described" [probably that at Ballaterson Mooar, or Dollagh Mooar of Ordnance map, alluded to by Mr. Kermode], "the marl lies at a depth of from 4 to 6 feet only, being covered by a hard, sandy, blackish earth. The field in which it is situated is crusted over with wet soil. Before the surface of this basin was broken up, it had a thin layer of turf upon the middle or deepest part of it, but there is none now to be seen. Between the alluvial covering and the marl there is a bed of dark turfy, fibrous earth, from 2 to 4 inches thick, each horizontal layer showing different degrees of shade. The marl is darkest near the top, continuing thus to a depth of 18 inches. In this upper part of the marl slight veins or rents occur. This marl is also fibrous, and somewhat slaty, and exhibits between its layers white delineations like grass. It likewise contains bones, but they are few in number, and much decayed; of these are pieces of ribs, condyles of bones, and stems of large horns, etc. This deposit of marl, though near the surface, and in a field almost level, is basin shaped, like that last described, varying in depth from 7 to 10 feet in the middle, and passing out to the thinness of a few inches at the margin."

The basin last mentioned is probably that at the margin of which Dr. Hibbert saw a section which he describes¹ as showing, at the base, 3 feet of marl mixed with sand and small pebbles of clay-slate and quartz; covered by 1 foot of the same substance mixed with more sand and containing some little vegetable matter; above which was 1 foot of sand mixed with white quartz pebbles; then 6 inches of drift peat, 6 inches of black mould, and over the whole a thinner coat of drift peat.

Dr. Hibbert illustrated his paper by a figure and measurements of a skull and antlers at that time in the possession of Dr. Burman of Douglas (op. cit., Pl. II., fig. 1); this specimen, Mr. Kermode thinks, may be the specimen afterwards acquired by J. F. Campbell of Islay; but the measurement of the Islay antlers

¹ Edinburgh Journal of Science, vol. iii. (1825), p. 27.

seems to indicate a smaller example than that figured by Hibbert.¹

In another communication on the subject in the same volume (p. 129) Dr. Hibbert suggests, on the authority of Dr. Burman, that a second species, "apparently of the present race of elks which inhabit the north of Europe," occurred in the marl of Ballaugh; but the evidence is altogether insufficient, since the antler figured (Pl. II., fig. 3) in support of his view was not the actual horn found at Ballaugh "but that of a recent animal of the same kind from Norway," in Dr. Burman's possession, which was thought exactly to resemble it, the discoverer of the fossil not being willing to part with it.

Cumming, who found the original sections no longer accessible, was at first of opinion that the elk belonged to the later portion of Post-glacial times,² but afterwards changed his views, stating that "on closer examination I find good reason for concluding that the white marl [of Ballaugh] is . . . perhaps more ancient than the Jurby marl, though this is apparently an alluvium older than the forests of which the remains are found in the Curragh."³

Edward Forbes (who was a Manxman by birth, and spent part of his youth at Ballaugh), in discussing the elk in his classical memoir "On the Geological Relations of the Existing Fauna and Flora of the British Isles," expressly states that the basins of fresh-water marl in which the bones were found were "distinctly, both in the Isle of Man and Ireland, overlaid by the peat, with its ancient included forests," and he illustrated this arrangement by a diagram representing the Ballaugh section.⁴

Thus these old records show clearly that none of the Ballaugh elk-remains were found in the forest-peat, but all in the lower marl, which was separated from the peat by a bed of sand. Equally clear is it that this sand represents the horizon of the recently discovered Arctic remains of the Loughan Ruy section given on p. 375, as will be recognised on comparing this section with those described by Henslow (p. 379) and Oswald (p. 380).

These Ballaugh hollows are in a porous substratum of gravel, but are close to the margin of the Curragh, and would all be filled with percolating water when that area was a fresh-water lake. Further investigation is required to decide whether the accumulation of marl was stopped in Loughan Ruy by the gradual silting up of the pool, or whether, as has been suggested, it may have ceased upon a change of climatic conditions.⁵ The sand and gravel overlying the marl were evidently washed in from the margins; and probably in part represent the shore-

¹ *Yn Lioar Manninagh*, op. cit., p. 398.

² *Quart. Journ. Geol. Soc.*, vol. ii. (1846), p. 344.

³ "Isle of Man" (1848), p. 216, foot-note.

⁴ *Memoirs of the Geological Survey*, vol. i. (1846), p. 394.

⁵ See Report of Irish Elk Committee, *British Assoc. Rep. for 1897*, p. 347.

deposits of the pool synchronous with the marl and peat of the middle of basin.

We will now turn to another well-known locality where the elk has been found in the Island. Hibbert (op. cit., p. 17) mentioned that "about a mile to the north-west of the Tynwald Hill, at a short distance from the Peel [Neb] River, there is a low marshy piece of ground from which large quantities of shell marl have been procured, . . . and in this marl numerous bones of the elk have been observed in an imbedded state. . . . The shell marl . . . is of a milk-white colour, also, when dried, very light and porous. All the shelly portions are in such a comminuted state, and so mixed up with clay and sand, that I could not find a specimen in which the organic structure of the animals to which the marl owes its origin was preserved." [Later researches have shown this to be a 'chara-marl.'] "The bones of the elk are said to be found about 6 to 10 feet deep in this marl, and mixed along with them, particularly in the more superficial strata, are the remains of numerous aquatic plants, as of willows, ferns, reeds, etc., indicative of the ancient marshes which succeeded to the levelling of the land, and to which the elks appear to have resorted. In the upper beds the calcareous matter gradually lessens. . . . A stratum of sand, the pure and nearly unmixed debris of the neighbouring hills, is superjacent to the shell-marl, while a comparatively modern bed of peat covers the whole."

Cumming also refers to this locality;¹ and Mr. Kernode had collected information as to specimens found here.² It was therefore selected as a site for further exploration by the British Association Committee, with the result that a large and nearly perfect skeleton was exhumed in 1897. Through the energy of Mr. Kernode this fine specimen has been carefully restored and mounted, and is now preserved in Castle Rushen at Castletown.

The conditions under which it occurred resemble in most respects those at Ballaugh. An uneven platform of sandy and gravelly glacial deposits, extending inland from Peel to the foot of the mountains (pp. 457-8), is broken towards its southern margin by several little basins. From these basins small valleys lead southward to the broad hollow drained by the Neb between St. John's and Glenfaba, which has wide gravel terraces on both sides, and appears to have been occupied by a lake in late-glacial times (p. 410). The site of the excavation was at the south-western side of the Close-y-Garey basin, on the eastern side of the railway line 400 yards south-west of the farmstead of Breck-y-Broom (6-inch Sh. 9). As reference to the geological one-inch map will show, this little irregular basin, about 200 yards long by 40 to 100 yards wide, is only separated from another somewhat larger depression to the eastward by an esker-like ridge of sand and gravel from 50 to 100 yards wide; and the two are connected

¹ "Isle of Man," p. 182.

² "Yn Lioar," op. cit. p. 399.

at the southern end by an old drainage channel, which is prolonged into a little valley opening southward to the upper gravel platform of the Neb valley near Ballaleece, at an elevation of about 105 feet above O.D. (p. 458). The following passages describing the results of the excavation are quoted (not in their original order) from Mr. Kermode's Report¹:—

"About sixty years ago the bog had been worked for marl, and the present well-defined banks mark out a rectangular hollow some 50 yards square and about 3 feet below the surrounding surface. Across one corner of this a trench was dug to carry off the water, and the operations of the Committee were confined to a triangular area on the west side of the trench, measuring about 15 yards east and west, by about 30 yards north and south. . . .

The result of all the excavations, allowing for the disturbed state of the ground, showed the following beds:—

	Ft.	in.
A. Disturbed soil and peat, an average of about	3	0
B. In one place a blue clay or silt was observed resting on the white marl.		
C. White marl containing the Elk remains	6	6
D. Blue marl ²	1	0
E. Red sand with gravel	0	3
F. Brown clay	0	3
G. Sand and gravel } Glacial drift {	0	3
H. Clay	4	0

As stated above, the whole surface had been lowered about 3 feet in digging for marl; the peat had for the most part been removed, and a great deal of the marl also; indeed, we were fortunate in finding this one spot in which the marl itself had not been disturbed.

The finding of detached bones shows that other individuals had perished here. . . . In association with these were remains of horse, represented by a radius and lower jaws of two individuals. Though the ground had been disturbed the horse bones probably belonged to the same age as the elk. A fragment of a metatarsal, met with in digging the trench, had an artificial perforation.

The skeleton lay in white marl at a depth of about 9 feet from the present surface, on its right side, the legs drawn up to the body, the head towards the margin of the ancient pool, now a morass, which lies in a hollow in the glacial drifts.

From the position of the bones the animal appeared to have died where it was found, not to have been washed down by floods. . . .

The bones were nearly all in juxtaposition and, excepting the ribs and pelvic bones and one shoulder-blade, in a very fair state of preservation. The antlers were nearly complete; the beams, however, are represented by fragments, the skull also is fragmentary.

The left antler is the larger; it measures across the palm 15 inches, allowing for a piece of the front edge which has decayed away; the right measures 13 inches. With the tines, most of which dropped off on lifting from the marl, they are respectively 56½ inches and 53 inches long, and the beam would have been about 10 inches more. They show six points, besides the brow-tines, which had fallen off, the portion of the beam to which they were attached having decayed away.

¹ British Assoc. Rep. for 1898 (Bristol), pp. 548-551. The report contains full measurements of all the bones of the skeleton by Professor W. Boyd Dawkins.

² "This was noticed below the skeleton, and may have been discoloured by the decay of the body."

The palm of the left antler lay over the lumbar vertebrae, and the right over the forequarters. The upper jaw teeth were preserved on both sides, and those of the left lower jaw were embedded in the *ramus*. A fragment of the right symphysis was also present, and there were various fragments of a skull which had been broken up before the discovery. Death had occurred in its full prime, as shown by the perfection of the teeth and the dimensions of the antlers.

Among the bones, but not of this individual, was one which had been perforated, probably by the point of an antler of another elk in one of their usual fights. It was fractured as well as perforated, and had been healed.

Samples of the marl and other beds were forwarded to Mr. James Bennie, of Edinburgh, who again most kindly undertook the laborious task of washing and sifting the material. The organic remains thus obtained were examined by Mr. Clement Reid, who has determined the following plants:—

From Peat B [A ?].

<i>Ranunculus Flammula</i> , <i>L.</i>	<i>Carduus crispus</i> , <i>L.</i>
<i>Viola palustris</i> , <i>L.</i>	<i>Menyanthes trifoliata</i> , <i>L.</i>
<i>Rubus fruticosus</i> , <i>L.</i> (very small).	<i>Empetrum nigrum</i> , <i>L.</i>
<i>Potentilla Tormentilla</i> , <i>Nestl.</i>	<i>Potamogeton</i> , sp.
" <i>Comarum</i> , <i>Nestl.</i>	<i>Carex</i> , 4 sp.

Also beetles, 3 sp., and caddis cases.

From Marl C.

<i>Ranunculus repens</i> , <i>L.</i>	<i>Empetrum nigrum</i> , <i>L.</i>
<i>Viola palustris</i> , <i>L.</i>	<i>Potamogeton</i> .
<i>Potentilla Comarum</i> , <i>Nestl.</i>	<i>Carex</i> , 4 sp.
<i>Myriophyllum spicatum</i> , <i>L.</i>	<i>Chara</i> .
<i>Rumex obtusifolius</i> , <i>L.</i>	Umbelliferous plant (unripe).

From Red Sand E.

Plant remains, not determined.

From Bed F.

<i>Betula alba</i> , <i>L.</i>	Bracts of sedge.
<i>Potamogeton</i> .	Leaves. (?)
<i>Carex</i> .	

Mr. R. Okell examined the White Marl for Diatoms, but found no trace. There are no fresh-water shells in it."

Mr. Reid, in reproducing the above lists in his recent work on "The Origin of the British Flora,"¹ remarks: "B. is Recent or Neolithic, C. and F. [*E. in Mr. Reid's book*] correspond with the marl at Ballaugh, and are classed provisionally as Late Glacial."

It will be noticed that the 'stratum of sand' mentioned by Dr. Hibbert as occurring between the marl and the peat was not found in the recent excavation, unless represented by the patch of the blue clay or silt, B., of which, unfortunately, no specimen was preserved. If its absence be not accounted for by the disturbed condition of the upper portion of the section, the bed may possibly have been originally limited to one part of

¹ Dulau and Co., London (8vo.): 1899.

the basin. It was at a corresponding horizon in the Ballaugh section that the Arctic remains were found; so that if the bed could have been examined, it is possible that similar remains might have been found at Close-y-Garey, since the general similarity between the sections is so close.

Of the other localities in which elk-remains have been found in the Island we have little definite information. Cumming, writing in 1861 ("Guide Book," p. 112), stated that "in the alluvial gravel in the Valley of Glen Mooar [near St. Johns] were discovered, 30 years ago, some fine specimens of the *Cervus megaceros*," but gives no further details, and may possibly refer to the Close-y-Garey finds. He also mentioned ("Isle of Man," p. 56) that some remains of the animal had been turned up in the south, near Castletown, from a whitish marl underneath a patch of turfy ground in a field in the Silverburn valley opposite Creggans; and again (Quart. Journ. Geol. Soc., vol. ii., p. 345) that he obtained the right pelvis of a *Megaceros* from blue alluvial marl on the Balladoole Estate, at a depth of six feet, the marl being covered by 2 feet of "marine sand." In the same neighbourhood, it is recorded by Mr. J. M. Jeffcott¹ that fragments of an antler of the elk were found in the peat on the beach at Strandhall, probably the specimen now in the possession of Mr. J. M. Gawne (see p. 414); and Dr. Clague, of Castletown, possesses an antler from Kentraugh.² In the north of the Island, at Ballalheaney near Andreas, an antler was dug up from a bed of peat covered with sandy wash, at a depth of 4 feet (p. 436).

In reviewing the above evidence, we find that wherever the details of the sections are known, the elk-remains have been obtained from the lowermost portion of the alluvial deposits, and from beds which contain the first indications of organic life after the emergence of the land from under the ice-sheet. In this respect the Manx evidence is in full accord with what is known of the principal occurrences of the elk in Ireland. Indeed the similarity of the Loughan-ruy and Close-y-Garey basins to the best-known Irish sites is remarkably close, both in topographical situation and in the general sequence of the deposits; as will be seen on comparing the sections given above with that of the Balleybetagh Bog, 9 miles south-east of Dublin, described by Mr. W. Williams³ as a typical Irish locality; or with the generalised Irish section reproduced in a recent number of the *Geological Magazine*⁴ from Mr. J. G. Millais' book on "British Deer." In Ireland as in the Isle of Man, the elk-remains are embedded in marl at the bottom of hollows in the drift; the marl is covered by clayey, silty, or

¹ Yn Lioar Manninagh, vol. i, pt. 2, p. 56.

² Kermode do. vol. iii., p. 400.

³ "On the occurrence of *Megaceros Hibernicus* in the ancient lacustrine deposits in Ireland," Geol. Mag. (new ser.), dec. ii., vol. viii. (1881), pp 354-363.

⁴ Geol. Mag., n.s., dec. iv., vol. v. (1898), p. 133 (review of "British Deer and their Horns" by J. G. Millais).

gravelly wash; and this again by peat, sometimes containing trees. Moreover, in both districts the marl is a *Chara*-marl; and in regard to this, Mr. C. Reid has made the following apposite suggestion:—"Those familiar with the pools containing *Chara* will be well aware of the appearance of shallowness and of a solid floor, which is so deceptive. The *Chara* and *Potamogeton* may grow from a depth of several feet, but they often appear to form a carpet of bright green turf a few inches under the surface of the clear water. Any animal treading on this turf would immediately plunge head-foremost into the water, and the wide-branching antlers of *Cervus megaceros* would become entangled amid the *Chara* stems, and still tougher Pondweeds, so that the animal would have scarcely a chance of escape."¹

The plant-remains found in the Irish marl are most, if not all, species which occur also in the Manx deposits; Mr. Reid remarks that they are "all of wide range, and throw no light on the climatic conditions that held during the *Megaceros* period." Arctic remains corresponding to those of the Isle of Man have not yet been found in Ireland, probably, as Mr. Bennie suggests,² because proper search has still to be made. Mr. Williams is of opinion that the elk-marls were accumulated in Ireland during a mild and genial interlude which followed the cold wet climate of the great thaw, and was succeeded by a return of glacial conditions, "the cold of this period having probably exterminated the *Megaceros* in Ireland."³ In the last (third) edition of his "Great Ice Age," Prof. James Geikie to some extent endorses this view, and after discussing the evidence concludes,— "it seems to me probable that the *Megaceros*-beds may be of interglacial age—that, in short, they may occupy the horizon of the interglacial deposits of the Baltic coast-lands."⁴ Mr. Reid in his report on the plant-remains from Ballaugh has the following pertinent remark:—"It is important to ascertain whether there is any evidence in the Isle of Man of a mild period after the melting of the ice, and before the deposition of the bed with Arctic willows. If the shell-marl (F) containing the *Megaceros* remains was formed during a mild interval, the complete disappearance of the Irish elk, so difficult to understand, may be due to cold or to scarcity of food during a less genial period. This point has never been cleared up in Ireland, notwithstanding the numerous remains of the Irish elk that have there been obtained."⁵

In view of such evidence as that recently obtained at Hoxne and other places⁶ for wide-reaching alternations of climate since the departure of the last great ice-sheet, it would be rash to

¹ "The origin of *Megaceros*-marl," "Irish Naturalist," May, 1895.

² "Irish Naturalist," April, 1894.

³ Op. cit., p. 362.

⁴ "Great Ice Age," 3rd ed., p. 417.

⁵ British Assoc. Rep. for 1897 (Toronto), p. 348.

⁶ See C. Reid. "Rep. British Assoc. for 1896, pp. 400-415; also "Origin of the British Flora." Lond. 1899.

deny the possibility of the *Megaceros*-marl being the product of a genial interval between two cold periods; but so far as the Manx evidence alone is concerned, there appears to be no necessity for the theory of alternating climates, as all the known facts seem consistent with a regular amelioration of temperature, such as might accompany the gradual disappearance of an ice-sheet.

For reasons which are discussed on a subsequent page (p. 396) it is probable that a great amelioration of climate had come about before the Island was uncovered by the waning glacier, and that the conditions were favourable to the growth even of comparatively temperate-climate plants as soon as ever these could find footing on the emerging land-surface.

Hence by the time that the ice had sunk to the foot of the hills the land was probably clad with verdure, and offered tempting pasturage for the great elk, just as the Barren Lands of Northern Canada and the tundras of Northern Siberia, under somewhat similar conditions, at present constitute the favourite feeding-ground of its living analogues. The flora, as Mr. Reid notes, consisting almost entirely of a few common species of wide range, is exactly the vegetation which we should look for to be first established in such an area; and its dispersal could scarcely fail to be assisted by hairy migratory animals like the elk. If there had been forest growth at the time we should not have failed to find trace of it in the marl, where its absence is conspicuous. Indeed, one can scarcely imagine the elk to have originally developed such wide-spreading antlers in a forested country, though the species, elsewhere originated, might manage to survive for a time among forests. The little Arctic crustacean and the Arctic plants were probably contemporaneous with the elk, and are indications of the proximity of the ice-margin when the animal first reached the area. It is true that only a single example of the crustacean and none of the Arctic plants have yet been found in the marl with the elk; but this is probably an accident of preservation, as seeds only have endured in this material, and the Arctic willow is represented by leaves alone in the overlying bed. The relationship of the sandy beds to the marl in these little basins seems to be that of shore deposits to deeper water sediments, their accumulation going on contemporaneously, but the former gradually overspreading the latter as the pond contracted and grew shallow.

It seems reasonable to believe, as elsewhere suggested (pp. 397-8), that the elk, possessing the instincts of its living representatives, may have reached the Island, and Ireland also, across ice-fields when a remnant of the great glacier still occupied the sea-basin; and it may never have been a permanent resident, but only a migratory visitor. The animal may have lingered on into the age of forests, when the principal peat bogs of the Island were accumulated; but for this there is at present no positive evidence.

Our enquiry, therefore, leads us to the conclusion that *Cervus giganteus* in the Isle of Man must be regarded either as a Late-glacial or early Post-glacial inhabitant according to the limits, in any case arbitrary, which we may assign to the Glacial Period.

THEORETICAL CONCLUSIONS AND REVIEW.

It remains now to combine the inferences drawn from the facts into a short history of the probable course of events in this part of the Irish Sea basin from the beginning of the Glacial Period to its close.

The fundamental deduction, that an ice-sheet must have filled the depression surrounding the Island, is merely a re-statement of the conclusion forced upon many previous workers, including R. H. Tiddeman,¹ J. G. Goodchild,² and J. Geikie,³ by their studies on the mainland; and upon J. Horne,⁴ the late H. Carvill-Lewis,⁵ and P. F. Kendall,⁶ by their personal examination of the Island. It is on subsidiary points as to the conditions during development and disappearance, and as to the direction of flow of this ice-sheet that the present investigation has thrown fresh light.

Of Pre-glacial conditions in the Island we gather faint glimpses only, from topographical evidence and from the shells in the drift. No deposits of this age have anywhere been found below the glacial beds, not even in the deep borings of the north, where the base of the drifts was far below sea-level. The presence of so much marine detritus in the drifts and the absence of any land-remains seem to indicate that the Island was surrounded by the sea right up to the advent of glacial conditions. The broad platform of erosion at the foot of the Pre-glacial cliff-line shows that this sea must for a long time have stood at approximately the present level; and afterwards have sunk somewhat lower, since this platform has in places been trenched by streams. From the character of the shells derived from this sea-bottom and incorporated in the drift, the marine conditions may date back to Late Pliocene times, but not earlier; their mixed *facies* and the presence of northern species betoken a changing climate; and the far-travelled pebbles coated with marine organisms indicate the presence of floating ice before the marine conditions terminated. Whether after being supplanted by the ice-sheet, the sea ever recovered its basin until the close of the Glacial episode, is doubtful. The only evidence in favour of its having done so is the presence of the belt of

¹ Quart. Journ. Geol. Soc., vol. xxviii., p. 488.

² Quart. Journ. Geol. Soc., vol. xxxi., p. 56; also "Ice work in Edenside," Trans. Cumberland Assoc., No. 12 (1886-7), p. 111; and other papers.

³ "Great Ice Age," map, pl. 1, p. 69 *et passim*.

⁴ Trans. Edinburgh Geol. Soc., vol. ii., pt. iii.

⁵ "Glacial Geology of Great Britain and Ireland" (1894. Longmans: London and New York), p. 359.

⁶ In Lioar Manninagh, vol. i., p. 397.

marine material among drift of the usual character in the deeper part of No. 6 Boring, at over 200 feet below sea-level; and as we have already seen, this material may possibly represent strips of the old sea-bottom not redistributed piecemeal like the rest, but displaced *en masse* by the ice-sheet. The juxtaposition of a band in which the comparatively deep-water *Rhynchonella psittacea* is the most abundant shell with another in which the shallow-water *Mytilus edulis* plays that part, is scarcely compatible with original deposition; and the indefinite character of the evidence in the other borings is likewise unfavourable to the occurrence of a true marine horizon in this part of the drift.

Even if the shell-bed be in place it need not denote more than a minor variation of climate during the growth of the ice-sheet, which changed its general advance over the sea-bed to a temporary retreat. Under such circumstances, strips of sea-bottom with northern shells might become locally interspersed with the basal moraine. But one thing seems clear, that nowhere in the Manx drifts do we find evidence for an Inter-glacial Period in the sense in which that term is usually understood, *i.e.*, of a warm period during which a previously existing ice-sheet entirely disappeared, afterwards followed by the growth of a new ice-sheet. All the known facts support Mr. Kendall's conclusion that in this area "the glacial period was one and indivisible, and that any withdrawal of the ice and re-advance over a spot, was merely such an oscillation as is observable in the case of the glaciers of the Alps, and of other places."¹

The state of the climate in this region at the beginning of the Glacial Period was undoubtedly such that the snowfall accumulated from year to year, at the comparatively low altitude of the hills of the Island and of the uplands of the mainlands surrounding the Irish Sea, so that the valleys became filled with glaciers. Along the shores an ice-foot probably formed in the winter and broke away in the summer into floes, which distributed their burden of rock-fragments broadcast over the sea-floor. This seems to be the explanation of the curiously wide dispersal of the fragments from Ailsa Craig, which have been recognised in the drift almost all round the northern part of the Irish sea-basin, in Ireland and Wales, as well as in the Isle of Man.² The sea-girt precipices of splintery rock in Ailsa could not fail to cast off a load upon an ice-foot below; and thus these fragments became strewn over the sea-floor almost as widely as the shells, and were subsequently carried by the ice-sheet into nearly every district to the southward where the shells were carried.

Gradually the permanent snow-line crept downward on the hills, and the glaciers crept outward into the shallow sea, perhaps

¹ Op. cit., p. 424.

² Kendall, op. cit., p. 407; J. Lomas, British Assoc. Rep., 1892, p. 707; G. A. J. Cole, "Nature," vol. xlvii., p. 464.

in the deeper channel partly afloat like the great glaciers of some of the Greenland fiords; until at length the open water-surface was obliterated, and an icy bridge stretched from Britain to Ireland, with the Isle of Man as its central pier.

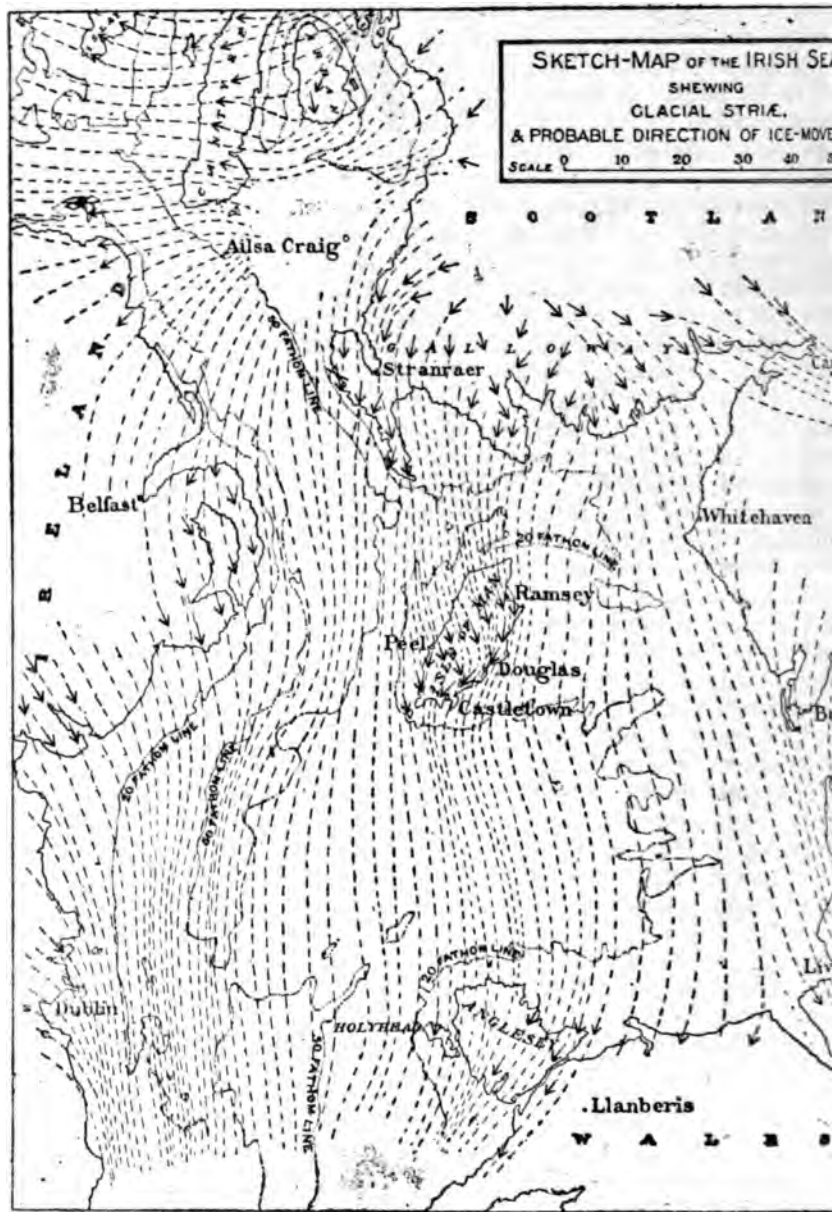
Then ensued a set of conditions to which I would especially call attention, as I think they have hitherto been almost overlooked by students of the subject. Up to this time the hill-ranges surrounding the basin had played the chief part in the production of the land-ice; and had formed independent centres of ice-drainage, as proved by the dispersal of their boulders, corresponding in the main to their previous systems of water-drainage. But when once the glaciers had overspread the enclosed sea-basin, they would constitute an ice-sheet which with the then-existing climate could grow independently, even at a comparatively low elevation, from the accumulation of permanent snow upon its own surface. And as the flow from the hills would also continue, without any compensating discharge from the low ground, the ice would rapidly increase in depth in the basin, like water under similar circumstances, without proportionate increase on the high ground.

In any irregular land-area undergoing glaciation there must be this general tendency towards the obliteration of surface-relief. In the present case the ice-plateau in the basin rose higher and higher, from the above causes, until the relative importance of the hills as centres of glacial flow was lost, and the direction of movement of the mass was determined by independent factors and particularly by the position of the area of maximum thickness in the ice-sheet. In the earlier stages the snow-fall, like the present rainfall, was no doubt heaviest on the hills; but as the ice-sheet increased in elevation, its surface must soon have lain high enough to rob such moderate heights as those of the Lake District or the Southern Uplands of their advantage, and to arrest a precipitation at least as great as their own, and over a much wider area.

Moreover, as the principal moisture-laden winds, then as now, must have come in from the Atlantic, every increase in the elevation of this western ice-plateau would tend more and more to intercept and lessen the downfall upon the hills to the eastward, and correspondingly to increase its own rate of growth. And the greater its altitude the less would be the thawing of its surface during summer. Hence, given the initial circumstances, the growth of an ice-sheet in such an area must proceed at an increasingly rapid rate, until its dimensions bring retarding factors into play, or until the secular conditions become unfavourable.

The growth of the West-British ice-sheet went on until, in the vicinity of the Isle of Man, as shown by the high-level striæ, its surface was, at least, more than 2,000 feet above present sea-level, while its base was from 400 to 800 feet below that datum-line in the deeper part of the basin to the north-westward of the Island. With a total thickness, as thus indicated

FIG. 103.



of not less than 3,000 feet, this sheet had, as we know, attained great lateral extent, reaching at this time south-westward to the Irish margin of the basin, and southward and south-eastward to North Wales and Lancashire. Hence, as already pointed out, the drift-phenomena of the Island are of especial importance to the glacial geologist in showing conditions in the heart of the sheet, which explain many difficulties met with in the marginal districts.

Let us consider, for example, the direction of ice-flow over the Island in relation with its direction on the mainlands, as shown on the sketch-map, Fig. 103.¹ We obtain, I think, clear proof that, at the maximum stage of the West-British ice-sheet, its principal centre of dispersal lay, not among the hills, but over an area in the basin somewhere in the region of the North Channel, where presumably the ice had accumulated to its greatest altitude. The divergence of the Clyde ice westward over Cantyre; of the Galloway ice eastward up the Solway Firth; of the Lake District ice south-eastward up and over the watershed of the Eden Valley and southward across Morecambe Bay; and of the East Irish ice southward along the coast, all indicate that the uplands had lost control of the flow and could barely defend themselves from actual invasion. As for the local accumulation on the Manx hills, like the hills themselves it had ceased to be distinguishable beneath the surface of the plateau, and had become part of the general current moving south-south-eastward. The influence of the Island upon this current was exactly that of a sunken boulder in a river, and no more.

The upper portion of the ice-sheet at this stage, having been derived from snow-fall on its own surface, must have been free from detritus, like existing ice-sheets of similar origin; but its lower part was no doubt laden with morainic material brought in by the original glaciers, and with marine débris from the sea-bottom over which the ice was passing. As the basal layers must have been under the enormous pressure, they would likewise frequently tear up the underlying rock floor in moving forward.

The much-discussed problem as to the physics of ice-motion is not of immediate consequence to the field-worker in glacial geology, who sees all round him the evidence that the moving mass behaved to all intents and purposes as a plastic body, be the cause what it may. On a plane surface or in an irregular basin the base of the ice-sheet would doubtless tend to obtain relief from superincumbent pressure by flow towards the point where the pressure was less severe. In this way, the basal drift-laden layers would move gradually outward, and to some extent upward, from the centre of the mass towards its circumference, the altitude they eventually attained above their starting point

¹ The striae on this map are taken chiefly from the published maps of the Geological Survey, with a few from other published sources, supplemented in regard to Anglesea by information kindly given by my friend, Mr. E. Greenly.

depending partly upon the shape of the ground, and partly upon the relative height of the column of ice at different points.

The inequalities of the old rock-surface undoubtedly played an important part in directing the flow of the lower layers of the ice-sheet. I fully agree with Mr. Kendall that "although glacier-ice can ascend slopes of considerable steepness, there is a certain critical angle which cannot be surmounted, and when that is reached, instead of overriding the obstruction, the ice cleaves and glides past on either side, while, if the obstruction be not very high, the upper strata of ice will move on over the top."¹

These considerations account perfectly for the distribution of the foreign drift with marine débris on the flanks of the Island: for the absence of such material from most of the high ground: for the direction taken by the local boulders: and for the bearings of the striæ on the rock-surfaces. The lower layers impinging upon the steep northern slopes swerved to right and left as an undertow; and the clean upper portion passed over them and also over the local ice filling the deeper valleys of the interior, and swept across the uplands transverse to the ridges, which were glaciated with their own débris only.

It has often been urged that the increase of an ice-sheet beyond a certain thickness would be rendered impossible by the liquefaction of its base by simple pressure. In view of the great thickness of the existing ice-sheets of the interior of Greenland and of the Antarctic, this supposition has not much weight; but if valid, it might perhaps explain the production of thick sheets of ground-moraine in regions of great pressure, through the constant liquefaction and elimination of ice from the drift-laden lower layers and the compression of the accumulated solid residue.

We have no positive evidence as to the maximum altitude which the West-British ice-sheet attained. That its thickness above the crest of Snaefell (2,034 feet) must have been considerable is proved by the striæ that cross the summit transversely to the contours; and similarly in the case of South Barrule (1,585 feet), by the rapid uplift of the Foxdale granite boulders to its top. Its altitude, independently of its thickness below ordnance datum, was therefore certainly not less, and probably greater here than on the northern borders of the Lake District, where according to J. G. Goodchild (whose results in this respect agree with those obtained by J. Clifton Ward and R. H. Tiddeman farther southward), "The upper limit stood somewhere between 2,200 and 2,400 feet above the present sea-level at the points where the ice-sheet attained its greatest thickness."² Farther south, over the Lancashire and Cheshire plain, its height seems to have been well below 1,000 feet.

Without pursuing the argument in its wider aspects, it may be stated that the same conditions appear to have obtained also in

¹ Op. cit., p. 426.

² Quart. Journ. Geol. Soc., vol. xxxi., p. 98.

the East-British ice-sheet, which occupied the bed of the North Sea. The Laurentide ice-sheet of North America, which gathered on the low Archæan plain and spread thence towards the Appalachian Highlands of the Eastern States, may be cited as a parallel example on a larger scale. In fact, all the great ice-sheets of the Glacial Period seem, after their earlier stages were passed, to have grown and spread from the snowfall which they received on their surfaces rather than from the inflow of upland glaciers.

As the British ice-sheets must always have received their increment principally from the moist Atlantic winds, it seems probable, as I have elsewhere suggested,¹ that without any change of climate, the centre of greatest accumulation and consequently of maximum glaciation would tend to shift steadily westward and south-westward as the icy plateau rose higher in the path of the moisture-laden winds and compelled their earlier precipitation. This effect would, moreover, be accentuated by the obliteration of the open water in the sea basins to the eastward. The West-British sheet might from this cause go on increasing, while its East-British and Pennine equivalents were already diminishing from lack of sufficient snowfall.

It is worth noting in this connection that in studying the drifts of East Yorkshire some years ago, I arrived at the conclusion that the ice-sheet of the North Sea had begun to diminish before the overflow from the westward across the Pennine Chain commenced, though the reason was not at that time clear to me.²

May not the cold dry "steppe-period" which has been recognised in Central Europe be a further result from the same cause?

For the above reason, the shrinkage of the ice-sheet covering the Isle of Man is likely to have commenced while the Welsh and Ivernian sheets were still increasing.³

But it was not until there had been a great amelioration of climate that the Island began to emerge from the waning mass. The duration of its burial we have no means of estimating; time passes unchronicled in the middle of an ice-sheet; and it is only at its margin that there is any record kept. We begin to get glimpses of events, however, as soon as the higher of the mountain-ridges were bare; and from that time onward the records lack nothing.

Just as there had been an automatic acceleration of the rate of growth of the ice-plateau with its increasing elevation, so by a reversal of the process, was there a corresponding acceleration in the rate of shrinkage while its melting was in progress.

¹ "Glacialists' Mag.," vol. 1, No 11 (1894), p. 231.

² "Drifts of Flamborough Head," *Quart. Journ. Geol. Soc.*, vol. xlvii. (1892), p. 428.

³ On a vastly larger scale, there appears to have been a similar shifting of the centres of glaciation in the ice-sheets of North America, see J. B. Tyrrell. "The Glaciation of North-Central Canada." *Rep. British Assoc. for 1897*, p. 662, and *Journ. Geol. Chicago*, vol. vi. (1898), pp. 147-160.

As above hinted, the shrinkage may have begun from a diminution in the amount of snowfall alone; but before it could proceed far there must have been a wide-spread change of climate, and an essential difference between the conditions of this stage and of the initial stage of the period.¹

At the beginning of the period the climate was such as to permit the permanent snow-line to descend nearly to sea-level; while when the ice-sheet had reached its maximum it was requisite that the climate should be warm enough to prevent snow lying permanently at over 2,000 feet above sea-level before a positive lowering of the surface by melting could take place. Thus, an ice-sheet already in existence may be able for a long time to withstand a climate in which it could never originally have accumulated; and ameliorating changes may attain an advanced state before their effect on such an ice-sheet becomes marked. But when the permanent thawing of the surface once commences, it must go on with accelerated rapidity as lower levels are reached.

It may be objected that the ice-sheet was perhaps melted back from its margin, or that it may have sunk to lower levels by gradual out-flow without equivalent replenishment. But the evidence is convincing that the ice around the Island, like that of Eden-side, so well described by Mr. Goodchild, "melted as it stood, and the waning ice-sheet did not pass in reverse order through the series of changes that accompanied its increment."² Its flow, always sluggish, seems to have been arrested by the changed conditions; and the ice disappeared from the hills before a new direction of movement of sufficient strength to leave a record could be established. In this way only can we explain the remarkable conformity of the phenomena in regard to the ice-flow in the Island, and the absence of any trace of subsidiary local glaciers at the close of the period.

It is clear that by the time the hill-tops had reappeared the Arctic conditions of climate had passed away, and permanent snow was no longer possible on rock-surfaces, even at the higher levels. The ridges then stood out as rocky nunataks above the sinking ice-fields, and hastened the withdrawal of the ice immediately surrounding them, in the same manner as the nunataks of existing 'piedmont' glaciers.

Further differential melting was almost inevitable under the conditions.³ On the surface of the ice-sheet the rate of liquefaction, whether due to warm air, direct sunshine, or rain, must have been approximately equal over wide areas, leading to a general lowering of the plateau; and the resultant water, whether flowing or stationary, could scarcely rise above the

¹ The writer called attention to this point in "Nature," vol. lvii. (1896), p. 245.

² "Ice-work in Edenside," Trans. Cumberland Assoc., No. 12 (1886-7), p. 134.

³ See "Outline of the Geology of the Isle of Man"; Handbook for British Assoc., Liverpool (1896), p. 179.

temperature of its icy bed. But the contemporaneous drainage from the bare ground might be endowed with considerable melting power, the initial temperature of the rainfall being increased by whatever degree of warmth the land-surface might possess. Hence, where land-streams impinged upon the ice, there would be an accelerated melting back of the mass and the development of depressions, in which the waters often accumulated in small lakes. The streams from these lakes, discharging principally across the ice, but touching the land in places, are no doubt mainly responsible for the excavation of the curious notches on projecting hill-spurs and the production of patches of stratified local drift on open slopes.

With the increase of the land-surface and the uncovering of lower ground this differential melting seems to have become still more pronounced; so that the whole Island was freed from ice while there was still an icy plain surrounding it. It was at this stage that the main features of the northern plain were produced. Nowhere in the Island along an equal extent of border is the discharge of drainage from the uplands approximately as great as in the north, where three great valleys (Glen Dhoo, Sulby Glen, and Glen Auldyn) have their mouths at the edge of the hills within a space of six miles. The combined effect of their waters was to beat back the ice-front into a great crescentic embayment, with its western horn approaching the mountains between Ballaugh and Kirk Michael, and its eastern horn, now in great part carried away by the sea, curving round towards Ramsey, while directly opposite the above-mentioned glens it lay four or five miles distant. The history of Lake Andreas, which filled this hollow, has already been followed and need not be repeated (pp. 372-3).

Similar circumstances accompanied the wane of the East-*British* ice-sheet in East Yorkshire;¹ and have doubtless prevailed wherever the 'piedmont' as distinguished from the 'alpine' type of glaciation has ruled.

The peaty layer in the late-glacial gravel platform at Kirk Michael, with its limited flora of wide climatic range associated with one or two Arctic types and with the little Arctic freshwater crustacean, affords us a further glimpse into the conditions of this stage. The ice-sheet in covering the whole Island must have blotted out all the previous life; so that in spite of the relatively rapid emergence of the land and its insular position, this flora and fauna must have been re-introduced; and, though scanty, they indicate that the thawing back of the ice had, at any rate, occupied sufficient time for the re-establishment of plant life. Toward the close of this period, therefore, the Island probably formed a green inviting lake-bordered nunatak rising out of desolate icy plains; and it is quite possible that the Irish Elk, and perhaps other animals, may have reached

¹ "Drifts of Flamborough Head," *op. cit.*, p. 425.

² See I. C. Russell, "Glaciers of North America," Boston, 1897, p. 3.

it by crossing the ice-fields,¹ just as the mountain-goat, fox, wolf, and bear are known, at the present day, to traverse the Malaspina ice-sheet of Alaska for many miles on their way to the Chaix and Samovar Hills, which in like manner rise out of surrounding deserts of ice;² and as the reindeer crosses the frozen sea from island to island off the Siberian coast.

The final disappearance of the ice-sheet from the vicinity of the Island may be considered as marking the termination of the glacial episode in the stricter sense, so far as this region is concerned, though the climate may have remained for some time longer less element than at present. There was no return of the glacial conditions, nor was there any submergence of the area beneath the sea. The record of the interval between that time and the present is contained in the fresh-water alluvial deposits, which will be dealt with in the next chapter.

SUMMARY.

The main conclusions of the preceding pages may be summed up as follows:—

1. The sea-basin surrounding the Island has been filled by an ice-sheet which, when at its maximum, attained an elevation of not less than 2,000 to 3,000 feet above present sea-level and completely overwhelmed the Island. This is proved by the character of the Glacial deposits; by their arrangement and relations to the solid features; by the glacial striæ and other forms of rock-sculpturing; and by the transport of the Insular and Extra-Insular erratic boulders.
2. The general direction of ice-movement was approximately, from north-north-west to south-south-east, being transverse to the main hill-ranges of the Island; but there was local deviation, probably in the form of an undercurrent, on the flanks and especially on the lee-side of the principal hill-chain.
3. The material of the pre-existing sea-bottom was incorporated into the lower layers of the ice-sheet and was redistributed by it in the form of shelly drift. This distinguishes the Extra-Insular deposits from the Insular drift of entirely local derivation, but the two are due to a common and contemporaneous agency.

¹ In making this suggestion in a letter to "Nature" (Jan. 13th, 1898, vol. lvii., p. 245), I supposed it to be original, but find that it had been made long previously in regard to Ireland by Dr. J. R. Kinahan, who however believed that the frozen sea, and not the ice sheet, afforded passage to the great elk. (See G. H. Kinahan's "Geology of Ireland," p. 296.)

² See I. C. Russell, Thirteenth Ann. Report U.S. Geol. Survey, 1891-2, p. 26.

4. The glacial and post-glacial surface-features are shown to be wholly due to glacial, fluvio-glacial, and subaerial agencies. The sea has had no part in the arrangement of the drift deposits either during or since their deposition.
 5. The facts indicate an uninterrupted progression of events from the commencement of the glacial conditions to the period of maximum glaciation, and thenceforward to the amelioration of the climate and the disappearance of the ice-sheet. The sections offer no evidence for an interglacial period in this area.
 6. The West-British Ice-sheet which surrounded the Isle of Man and extended across the Irish sea-basin to the borders of England, Wales, and Ireland, probably attained its ultimate dimensions mainly from the accretion of snowfall upon its surface, and in only a minor degree from the inflow of tributary glaciers. The mass attained its greatest thickness in the area lying to the north-westward of the Isle of Man.
 7. During the closing stages of the period the melting of the ice-sheet in the vicinity of the Island was relatively accelerated at points of contact with the land-drainage, which was greatly in excess of that of the present day. The hollows thus formed between the retreating ice and the land were temporarily filled by freshwater lakes. A flood-terrace of this stage has yielded sub-arctic remains.
 8. The Irish elk probably made its first appearance in the Island while a remnant of the waning ice-sheet still lingered in the surrounding basin.
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CHAPTER X.

THE POST-GLACIAL AND RECENT DEPOSITS.

Historical and Introductory.

The detailed work as yet done on the Post-glacial deposits of the Island is scanty; and this is the more to be regretted since, from the persistence of fresh-water conditions in the hollows described in the last chapter, these alluvial beds afford excellent material for the study of the transition from glacial to present conditions. In certain localities in England and Scotland, where similar alluvial deposits have been carefully examined, great variety and perhaps alternation of climate is indicated during this period.¹ Traces of considerable changes are also forthcoming in the Isle of Man, where, as Cumming pointed out, the occurrence of peat with forest-trees below present sea-level, on the one hand, indicates a stage of elevation; while on the other hand, the existence of an old beach above that level indicates a stage of depression since Glacial times, and consequently much alteration in the physical conditions of the district.² As will be presently shown, it is, however, somewhat doubtful whether there has been a land connection with the mainland at any period since Glacial times.

In the earlier descriptions of the Island the alluvial deposits received greater notice than in later times, on account of their relatively greater economic importance when the peat-bogs afforded the main source of fuel and the marls were used for agricultural purposes. Bishop Wilson mentioned that the peaty curragh between Ballaugh and Ramsey, at one time bog, had become, since drained, one of the richest parts of the Island, supplying 'both bread and fuel'; and that in this place had been found "very large trees of oak and fir, some 2½ feet in diameter and 40 feet long . . . not promiscuously, but where there is plenty of one sort, there are generally few or none of the other."³ Henslow discussed the curraghs at considerable length, and noted that peat occurred also on the tops and sides of the mountains; besides oak and fir which, with hazels and their nuts, were the commonest remains in the peat, he recognised ash, walnut, black-alder, and in one instance, in a mountain curragh, holly; he also called attention to the statement by Sacheverell (see p. 16) and Bishop Wilson as to the majority of the trees having been snapped off and overthrown with their heads to the north-east;

¹ See C. Reid, "The origin of the British Flora," 8vo. Lond. 1899.

² "Isle of Man," p. 251-2; "Guide-book," pp. 171.

³ "History of the Isle of Man."

and described the submerged forest in Poolvash Bay.¹ His observations on the elk-beds at Ballaugh, and those on the same subject by subsequent investigators, were quoted in the preceding chapter (pp. 378-82).

Cumming's investigations have been already noted; and since his time, though the old observations have been frequently raked over, no real addition was made to our knowledge until the appointment in 1896 of the British Association Committee 'to examine the conditions under which the remains of the Irish Elk are found' (p. 383).

As the preceding account has shown, the fauna of the Post-glacial beds in the Isle of Man is extremely limited. Even including the elk-marls with these beds, the only mammal of which we have certain knowledge is *Cervus giganteus*, with doubtful records of *Bos longifrons*, and the red deer and horse (p. 377 and p. 384); while of the carnivora of this age so frequently found on the mainland no trace has yet been discovered. The absence of bone-caves and fissures may be partly to blame for this deficiency; but it is more readily explained by the suggestion of Mr. Kendall that the Island may never have been connected with the mainland since the Glacial Period. Mr. Kendall was led to this conclusion by the striking poverty of the existing flora and fauna in species, this poverty affecting the plants as well as the mammals, reptiles, amphibia, and fresh-water fish; after commenting on this fact, he remarks as follows:—"It seems to me that this extraordinary poverty of truly indigenous species in so many groups of organisms is well worthy of the careful consideration of naturalists and geologists, for, while to the former it presents an interesting problem for solution, to the latter it may not improbably prove of use as a check upon some of his speculations. For my own part, taking this evidence as it stands, the balance of probability seems to weigh heavily against any such complete connection with Great Britain as the oft-cited elevation of 600 feet would establish . . . and it seems to me incredible that if this whole tract [of intervening shallow sea] had been dry land during any considerable portion of the Post-glacial period, but two out of the thirteen reptiles and amphibia which inhabit Britain should have made their way across to the Island; that of the strictly fresh-water fishes three only should have been introduced; and of the forty British mammals but five should have made their way across. If a land connection was indeed established it must, I think, have been of very small extent and brief duration."²

In the present state of our knowledge it is hardly possible to classify the Post-glacial deposits of the Island strictly according to age. The only practicable method is to group them according to their topographical position. Hence they will be described under the following heads: (1) Raised Beach (with

¹ Trans. Geol. Soc., vol. v., pp. 499-503.

² Yn Lioar Manninagh, vol. i., p. 435.

Blown Sand); (2) Alluvium of the river-valleys; (3) Alluvium and peat of low-level basins; and (4) Hill-Peat. The general distribution of the first, second, and fourth of these divisions is implied in their titles; the third covers the northern Curragh, the western portion of the central valley, and parts of the low tract at the foot of the hills between Castle-town and Port Erin. Though the first is more restricted in age than the others, they are probably all more or less contemporaneous.

The less important local details are given, along with those of the Glacial deposits, in the next chapter.

The Raised Beach.

This beach is the only Post-glacial marine deposit above present sea-level recognisable in the Isle of Man. Its surface is 10 or 12 feet above high-water mark, or say 17 to 20 feet above the Ordnance datum of mean-tide level at Douglas. It appears to be newer in age than the older portion of the fresh-water basin-deposits (p. 415), but older than the latest of these. It attains its principal development in The Ayre at the northern extremity of the Island, where it consists of a succession of low storm-beaches of coarse shingle derived from the waste of the glacial deposits, partly covered by blown-sand. It has here a breadth of $1\frac{1}{2}$ miles in its easterly part, but tapers away gradually westward to 50 yards or less (see also pp. 417-22).

In one form or another this Raised Beach may be recognised on almost every part of the coast, except where it has been destroyed by the rapid encroachment of the sea, as between Jurby and Kirk Michael on the west, and between Cranstal and Ramsey on the east. In the deeper bays it often constitutes a low terrace only just above the reach of spring-tide storm-waves, on which the more ancient parts of the seaport towns have sometimes been established. In other places it may be represented only by a narrow rock-platform, occurring at intervals at the foot of the cliffs slightly above the present limit of erosion: or by caves and crannies whose excavation is now arrested. Numerous examples illustrative of these different conditions will be mentioned in the next chapter. Its shells, which are locally abundant, are those of the existing sea. It appears to surround the Island without perceptible difference of level.

The current belief, acquiesced in by Berger,¹ Henslow,² and Cumming,³ and based, no doubt, on the fresh aspect of the shingle, is that the Ayre beach is still growing rapidly seaward by additions to its margin (Berger mentioned two yards in a year as the reported rate, while Henslow thought this should be reduced by one-half), but the idea appears to be unfounded.

¹ Trans. Geol. Soc., vol. ii., p. 24.

² Trans. Geol. Soc., vol. v., p. 504.

³ "Isle of Man," p. 224.

In most places it is clear from the character of its margin that some degree of erosion has taken place, especially at the Point of Ayre, where the old straight-ruled storm-ridges stretching W.S.W. to E.N.E. are sharply truncated by the magnificent crescent of the present storm-beach curving boldly round the Point. At this place old plans of the lighthouse show that there has been no gain during the past century (see p. 417); and in several localities farther westward where the beach was recently paced, there has been no increase since the six-inch Ordnance map was made nearly thirty years ago.

We gain a valuable clue to the approximate age of this beach in the presence of Neolithic chipped flints on its surface in places. The shingle seems to have been resorted to by the ancient inhabitants for the sake of its pebbles of flint derived from the drift, which have sometimes been struck into flakes on the spot. So far as I could discover, after a search which may perhaps have been insufficient, these flakes though plentiful here and there on the inner part of the beach do not occur on its outer portion. Thus opposite Ballagenney, where the beach is about 1,100 yards wide and in many places bare of blown sand, I found the chips as far outward from the old cliff as 700 yards, but in the remaining 400 yards could detect none. Moreover, a little farther westward, I found in the outer part of the beach a single artificial flake which had been partially worn down by marine attrition, and must therefore have been in existence as a flake during the accumulation of this portion of the beach. Between Rue Point and Blue Point I found these chips also, in one place, in the blown-sand covering the inner part of the old shore. These facts denote that, at any rate, part of the platform was in existence in Neolithic times, but that it may not have attained its full breadth until after the close of that period.

The development of the Ayre beach has been due to strong currents and prevalent winds causing the eastward transference of material derived from the rapid waste of the west coast, and to its accumulation as a broad fan under the shelter of the northern cliff-line, at a time when slow elevation was in progress. The storm-beaches formed during elevation will not, of course, be so liable to re-arrangement by later storms as those of a stationary period like the present. The method of its accumulation is shown by the arrangement of its coarse shingle ridges, which lie parallel to each other, and have evidently been piled up successively at full-tide mark.

Cumming was of opinion that the elevatory movement might still be in progress;¹ but for this there seems no evidence; and the relation of the modern river-alluvium to the present beach at the mouths of the principal streams, at Ramsey, Laxey, Douglas, Peel and Castletown, is even suggestive of a slight depression.

¹ "Isle of Man," p. 252; "Guide Book," p. 171.

The Raised Beach formed a definite stage in the Post-glacial history of the Island, and indeed probably in that of the whole surrounding sea-basin, as an elevated margin of similar character occurs at about the same height in the east of Ireland,¹ and, slightly higher, in the south-west of Scotland,² and the north-west of England.³

The absence of the higher beaches which are found in Western Scotland (and in Ireland?) is noteworthy, and the whole subject deserves closer investigation. It seems not impossible that the waning West-British ice-sheet, shielded in its later 'piedmont' stages by the piles of débris concentrated on its surface, may have lingered longer in its enclosed basin than on the more open shores to the northward, and may have obstructed the return of the sea until a later period.⁴ But differential uplift, increasing northward, has probably also taken place; and this alone may be the explanation of the facts. The tracing of this particular beach northward on the mainland could scarcely fail to give results of interest.

Blown Sand.

The chief development of Blown-sand in the Island is on the inner belt of the Ayre Raised Beach, where it covers the shingle, sometimes evenly and sometimes in dunes. By heavily dressing the sand-covered surface with clay obtained from the adjacent old cliff of drift, some portions of this waste have been reclaimed and cultivated (p. 418). Although the sand is still in motion, its principal accumulation must have taken place long ago, as shown by the Neolithic flint chips which lie in or upon it, on The Ayre as already mentioned, and also at Ramsey (p. 430) and at Ballakinnag, near Ballaugh; as well as by its having been used for raising a pre-historic tumulus at Cronkbreck near The Lhen. Its distribution indicates that the prevalent winds have been from the westward ever since the period of the Raised Beach. In that quarter it covers the whole platform, in places even partly burying the ancient cliff and invading the margin of the drift-plateau above; while farther eastward it breaks up into small travelling dunes, leaving much of the shingle uncovered.

The narrow strip of Blown-sand, usually from 6 to 10 feet thick, which crests the high cliffs of drift for two miles northward from Orrisdale Head, presents some peculiar features. It is derived entirely from the winnowing of the stratified glacial

¹ G. H. Kinahan, "Geology of Ireland," p. 252.

² Mem. Geol. Survey of Scotland: Explans. of sheets 1, 2, 3, 4, 5, 7, and 9.

³ T. V. Holmes, Mem. Geol. Survey, "Country around Carlisle," p. 49; see also C. E. De Rance, Quart. Journ. Geol. Soc., xxvi. (1870), p. 655.

⁴ On parts of the coast of Alaska the sea is kept back in this manner at the present day; and a rich growth of vegetation, including forest trees, has established itself upon the morainic material which thickly covers the surface of the ice. (See I. C. Russell's description of the Malaspina Glacier in 13th Ann. Rep. U.S. Geol. Survey, pp. 19-21.)

deposits. The cliffs, ranging up to 100 feet or more in height, have boulder-clay at the base (see Fig. 104, p. 424) with much incoherent sand and gravel above, and weather into long talus-slopes at about the angle of rest of the loose substances. Up these slopes the on-shore gales sweep with great violence, forming a veritable sand-blast, by which the top of the cliff is notched, the sand being dropped in the aerial eddy on the crest. Not sand alone, but flat pebbles an inch or two in size, are sometimes carried up by this agency.¹ In this manner, though the cliff-line is receding rapidly under marine encroachment, it maintains a permanent sand-cap.

Precisely similar is the Blown-sand at a still higher elevation on Point Cranstal at the opposite side of the Island, though as east winds are less frequent than west winds, its extent is not so great.

In the south, minor tracts of Blown-sand, derived from the sandy shores of adjacent bays, are found at Castletown and on the isthmus leading to Langness; and at Kentraugh 3 miles farther westward.

Alluvium of the River-Valleys.

The present inert condition of the Manx rivers has been previously commented on (Chap. I., p. 10), and their alluvial deposits practically all belong to conditions no longer existing. Owing to the small size and rapid fall of the streams, the valley-bottoms are usually so narrow that in order to show their alluvial terraces on the 1-inch map it has often been necessary to exaggerate their actual breadth.

The presence of "flat terraces of rubbish" in some of the mountain-valleys was noticed by Macculloch, who recognised, from their prolongation on the lower slopes of the hills and on low ground, that these could not be assigned to ordinary fluvial action.² Cumming classed such high-level terraces along with the general drift of the hill-sides, as Diluvium; and accounted for them as accumulations "of an arctic climate existing at the period of the formation of the boulder-clay [of the lowlands]."³

To understand the position and mode of formation of these terraces, which overlie the drift at heights ranging up to 100 feet or more above the present streams, we must go back in imagination to the time when the ice-sheet first sank away from the hills, as described in the last chapter. Most of the hollows were then left deeply banked with local till and the slopes encumbered with slaty detritus; but the pre-glacial valley system

¹ On the northern side of Flamborough Head I have found platy fragments of chalk, up to 4 or 5 inches $\times$ 3 inches $\times$ 1 inch, which have been uplifted not less than 40 or 50 feet by the wind under similar conditions. These wind-driven materials form an exception to the general rule that denudation acts in the direction of gravity.

² "Western Isles," vol. ii., p. 525.

³ Quart. Journ. Geol. Soc., vol. ii., p. 341.

had not been disturbed, and the flooded streams resumed their old courses, though generally at a considerable height above their former rocky beds. Wherever the flow of such streams was arrested, part of their load was discarded; and soon the boulder-clay of the valleys was overspread with sheets of subangular rubble amid which the streams shifted perpetually to and fro, like the rivers of Iceland nowadays.¹

But the main streams soon trenched for themselves more confined channels in the boulder-clay; and in doing so, abandoned the higher platforms, and built up others, of more limited dimensions, at successively lower levels; until at last the old rock-floor of the valley was reached. Meanwhile every stream was laden to the full extent of its carrying power, so that quantities of slaty *débris* out of all proportion to the size of the valleys was spread out in fans and bars around the foot of the hills in the manner already described. In this way we may, without difficulty, explain all the phenomena of Manx valley-deposits. The regular descent with the valley which characterizes the terraces shows that they cannot be assigned either to marine action or to ice-dammed fresh-water lakes, but are truly fluvial. The higher of them may therefore be regarded as flood-gravels of Late-glacial times, equivalent to the gravel-platforms fringing the Curragh and other depressions, and they have been thus classified on the published map where broad enough to be separately distinguished.

With the dwindling of the rivers as time went on, the alluvial flats of the re-excavated channels became more and more restricted, and the material carried to the mouths of the valleys less and less in quantity; until the present conditions were reached, in which the streams even at flood can, for the most part, only struggle feebly with the ancient detritus in their beds. In their lower reaches, this enfeeblement may be due in part to the artificial robbery of their power for purposes of mining, milling and water-supply; but the fact that the heads of the glens generally have their banks grass-covered, even where formed of easily erodible drift, and their bottoms mere mossy bogs if not actually dry, is indisputable testimony of the changed conditions.

Alluvium of the Curragh Basins.

The early history and evolution of the great hollow at the foot of the slate hills have been recorded in the preceding chapter, and it is only with the later phases that we have now to deal. In the wider sense the depression extends southward up to the ancient cliff-line of the solid rocks (p. 6), and northward and westward up to the steep bank which marks the edge of the upper platform of drift (pp. 434 and 437).

¹ Dr. Tempest Anderson. Proc. Yorks. Geol. and Polytech. Soc., vol. xii, pt. ii. (1892), p. 165.

But the broad fringe of flood-deltas and terraces of Late-glacial age which have been thrown into it, especially in the west, have restricted the more recent alluvium to its central portion; and even in this part the flood-gravels stretch out from all sides in low banks and spurs which separate the tract into a series of more or less confluent basins differing somewhat in level. The most westerly of these basins is the peaty depression under the foot of Gob y Volley, one mile west of Sulby, at present the boggiest tract of the whole Curragh, though its surface in the lowest part is about 36 feet above O.D. and 15 to 20 feet higher than the easterly basin. Its infilling is principally peat of considerable thickness, which has been extensively dug for fuel; it is bounded on the west by the slaty gravels from Glen Dhoo and on the east by a partly buried spur of similar gravel from Sulby Glen. It drains to the west coast through an artificial trench leading into the Killane River, but might as readily have been connected with Lhen drainage going northward, or with that going eastward to Ramsey; and the same alternatives exist for all the western portion of the Curragh.

Another partly independent basin at about the same elevation lies around the southern end of the Lhen and extends westward in a narrow strip towards the Killane, having on all sides an ill-defined boundary on the gentle slopes of the sandy portion of the Late-glacial platform (p. 435); it contains but little true peat, its alluvium consisting chiefly of peaty sand, with a little gravel towards the margin. This appears to be the site of the 'Balla Lough' of ancient maps (p. 408); it is now drained and cultivated, part of its water going into the Killane and part into the Lhen.

The large irregular hollow farther to the eastward constitutes the chief portion of the Curragh. It is the tract over which the Sulby river has once expanded after leaving the hills and before finding its northward outlet by the Lhen; indeed, if it were not for the barrier of flood-gravel opposite the mouth of Sulby Glen, which now dams out the river and diverts it eastward, the hollow would still receive this water, its surface being for the most part 20 feet or more below the level of the river at the barrier. There are traces of a dry channel across the gravel-bar, 200 yards east of Sulby Church, which probably denotes a comparatively recent overflow of the flooded Sulby into this part of the Curragh; three-quarters of a mile farther east, where the barrier sinks, the river still occasionally overflows into another portion of the depression. The subsoil of the tract is variable, consisting mostly of peaty sand towards the northern margin, where the drift-slopes disappear very gradually beneath the alluvium; and in other places often of blue silt or mud (no doubt the finer waste of the slate-rocks), which frequently overlies peat containing large trees (see p. 439). The presence of this forest-peat shows that the area cannot have been continuously submerged, and may betoken a period during which, as at present, the river failed to cross the barrier, with a return of flood-water conditions at a later stage. The general level of the

surface in this part of the Curragh is a little over 30 feet above O.D., with a rise of several feet toward the mouth of the Sulby. East of Closechyrrim, irregular islands of dry sandy ground, probably elevations of the underlying uneven drift-surface, rise above the alluvial flat, and form a partial barrier separating the Sulby Curragh from that of Lezayre, which is on an average 10 feet lower in level, or about 20 feet above O.D. The latter depression expands northward into an embayment which appears to correspond to the 'Malar Lough' of ancient maps, and in part to the 'Lake Mirescogh' of the still more ancient chronicle (p. 439). The chief drainage-channels of the Andreas drift-platform now terminate in this embayment, which forms a flat alluvial meadow, underlain for the most part by greyish or bluish marl or sandy silt, with peat in a few places only.

This flat is bounded sharply on the east by higher sandy and gravelly drift-ground, which rises to over 90 feet above O.D. near the coast at North Ramsey, while on the south the alluvial basin is encroached upon by the delta-platform of slaty gravel lying around the mouth of Glen Auldyn. The tongue of alluvium thus narrowed is continued along the course of the Sulby River eastward into Ramsey Harbour, where we find that it merges insensibly into the Raised Beach (p. 440), though the sediments remain of fresh-water type close up to the town and within reach of high spring-tides.

In reviewing the facts in regard to the Curraghs as a whole, it becomes evident that after the shrinking back of the ice-sheet from the immediate vicinity of the island, the lake which had occupied the depression up to the 40ft. level found a fresh outlet eastward, and sank until its waters could no longer flow into the Lhen channel. Ridges and islands of dry land then emerged and broke up the water-surface into separate shallow basins, draining irregularly into each other, with a general fall eastward. The area of these lakelets varied greatly according to the season, only a few limited patches being permanently submerged.¹

Old maps of the Island, such as that of 1595 "performed by Thomas Durham," reproduced by Cumming ("Isle of Man," pl. IV.) from Speed's "History of Great Britain," or that of Chaloner of 1656, reproduced by Hibbert (Edinb. Journ. Sc., vol. iii., pl. II.) show three lakes on the northern plain, viz., one to the west of Andreas, draining to the Lhen; the second, named Balla Lough, to the north of Ballaugh, draining to the west coast by the Killane river; and the third, named Malar Lough, between Lezayre and Andreas, draining into the Sulby River and thence to the east coast at Ramsey. Owing to the imperfections of the maps these localities are not easy to identify, but the second and third, as pointed out above, probably occupied

¹ Exactly analogous conditions prevailed at this period in Holderness in East Yorkshire. See Mem. Geol. Survey, "Holderness," p. 77, and Proc. Yorks. Geol. and Polytechn. Soc., vol. viii. (1883), p. 249.

respectively the western and eastern portions of the Curragh, while the first seems to have been an extension of the present Lagagh Mooar (p. 432). Lake Myreshaw, or Mirescogh of the older records (see Cumming, "Isle of Man," p. 216), with its three islands, was probably an earlier condition of Malar Lough when its waters extended up to the Sulby River.

That these lakes were in existence in Neolithic times is indicated by the occasional discovery of implements of that age under the old alluvium, as recorded by Cumming in the following note:—"In some portions of the drained Curragh have been found stone celts and other relics of more ancient times, such as coracles which were probably sunk in these ancient lakes. I have in my possession a celt of the simplest kind, found under the peat on the edge of the Curragh near East Nappin. In a meadow adjoining Close Mooar, the property of Professor E. Forbes, were found a short time ago a stone axe and sharpening or edge stone, a few feet asunder. They lay upon a bed of fine sand, covered over with a stratum about 4 feet thick of peat-trunks of oak trees, etc., and over the peat was a bed of blue alluvial clay to the depth of 3 or 4 feet." (Op. cit. p. 216, footnote.)

There are several small alluvial hollows and flood-basins in the drift-platform to the north of the Curragh which are sufficiently described in the chapter of local details (p. 434-7); others of still smaller dimensions occur in the curious depression between Port e Myllin and Port Mooar south of Ramsey (p. 444), and near the west coast south of Orrisdale.

Alluvium of the Central Valley.¹

Much of the alluvium which covers the floor of the central valley throughout the greater part of its course can scarcely be assigned to ordinary fluvial action. The original preglacial excavation of this valley by streams flowing respectively east and west from the central hill-range has been discussed in an earlier chapter (I., p. 8). The ice-sheet deposited thick masses of drift in the hollow, of which that west of St. John's is mainly of the extra-insular type, while that east of Greeba is chiefly of local origin.

Upon the withdrawal of the ice, this infilling material underwent active erosion by the swollen waters from the hills; and was constantly being scooped out in one place and redeposited in another, until it reached the temporary lakes which, in this area as in the Northern Curraghs, were formed from time to time in different parts of the valley and emptied again as both eastern and western outlets deepened. The waters outpouring westward during the later stages missed the original valley for a short space at Glenfaba, $\frac{3}{4}$ mile S. of Peel, and cut a new gorge through slate and conglomerate, the preglacial channel probably lying a

¹ Berger used the designation "Glen of Mullin-y-Chlea" for this valley, from the hamlet of that name near St. John's, but the term if ever in common use is now forgotten. Trans. Geol. Soc., vol. ii., p. 33.

little farther eastward (p. 457). The check which this accident gave to the rate of erosion led to the development of a wide alluvial flat above the barrier. This flat is fringed on both sides by successive terraces, the highest of which, like those of the Curragh, probably date back to the period immediately subsequent to the retirement of the ice-sheet, while the lower deposits carry on the record through Late-glacial and Post-glacial times, down to the institution of artificial drainage at dates within the reach of history. To unravel the sequence of events in this tract as fully as it deserves would have required longer time than could be devoted to it during the present survey, especially as the lack of contours on the Ordnance map would have greatly impeded such work. While, therefore, the separate terraces have been indicated as far as possible on the published map, either as "Glacial platforms of sand and gravel" or as "Late-glacial Flood-gravels," it is not unlikely that different portions of the same or contemporaneous terraces may have lost their identity on the map.

As in other parts of the Island, the chief deposits of gravel form deltas around the mouths of the tributary valleys which open into the depression. Hence the largest is found near St. John's, where the Neb River comes in from the north and the Foxdale River from the south, the united deltas having apparently constituted a barrier across the valley which held up a narrow lakelet extending back to the col at Greeba, 2 miles farther east. The village of St. John's stands on the highest terrace (coloured pink on the map) at 150 feet above O.D. A large sand-pit in this terrace east of the railway-station shows 6 feet of rough slaty gravel with a few foreign pebbles, resting on 20 feet of cross-bedded sand containing crumbs of marine shells. Traces of a similar terrace exist here and there on both sides of the valley farther east; and during its accumulation there was probably an overflow across the Greeba watershed, but whether from west to east or from east to west has not been determined.

A lower terrace occurs on both sides of the Neb where it joins the main valley, at an elevation of 110 feet above O.D., falling westward to 90 feet or under on the northern side of the flat before ending off against the steep drift-bank east of Glenfaba. The little boggy basin which yielded the elk-remains at Close-y-Garey (p. 384) and other similar basins in the drift-plateau at Ballalough drain down to this terrace, which has been mapped as of Late-glacial age. On the opposite side of the valley, around Kirk Patrick and Ballamoore, we find traces of several terraces rising step by step from 40 to 50 feet above O.D. at the river-flat, to 110 feet at Kirk Patrick. The highest, which has been coloured on the map as 'glacial' (pink), runs up into the depression leading into Glen Meay (p. 458) and probably indicates a former inflow or outflow through the gap, but has been partially destroyed by later erosion. The little streams descending the steep northern slopes of Slieau Whuallian have each their delta

of flood-gravel, associated with one of the higher terraces; and these have been cut into on the subsequent lowering of the main valley. Similar features are seen at numerous points farther east, and are the outcome of conditions which have been described on a previous page (p. 406).

As the present river-flat rises eastward towards the confluence of the Neb and Foxdale streams, there attaining a level of 100 feet above O.D., the lower terraces merge into it and are no longer seen. The gravel-dam athwart the valley at St. John's is notched by a trench 30 to 50 yards wide, now artificially deepened, which permits the outflow of the arrested drainage above, where in ancient times lay the boggy lake of Curraghglass, in which, according to Cumming, it was the custom to plunge persons accused of witchcraft.¹ Though drained, the bottom of the valley between this point and Greeba is still for the most part boggy, and its alluvium consists of silt and peat, indicative of stagnant water. Its surface is now at from 135 to about 155 feet above sea-level; there is no evidence as to the depth of the superficial deposits upon the old rock floor, but it must be considerable.

In the Greeba pass the alluvial flat contracts, and at the same time begins to assume a gradual fall eastward. At the constriction it ends off on both sides against steep slopes of slate or drift, without terraces excepting at the mouths of the tributary waters which unite to form the River Dhoo, presenting characters more akin to those of an ordinary river-flat, except that its size is altogether disproportionate to its present drainage. The Ordnance map marks a level on its floor opposite Cregbeg with an altitude of 140 feet; another on the road across it at Ellerslie, $1\frac{1}{2}$ miles lower down, 117 feet; and the 100-foot contour² crosses it $\frac{1}{4}$ mile below the Ellerslie road.

An expansion of the valley in the last-mentioned neighbourhood, down to the constriction west of Union Mills, may have been occupied by a temporary lakelet. Its alluvium consists of 4 to 6 feet of silt with peaty layers towards the base, resting on slaty gravel. Down to this point the present River Dhoo is confined in a more or less artificial channel trenching the old flat; but after leaving this basin it has a natural course, with a more rapid fall, and down to its junction with the Glass near Douglas is bordered by narrow strips of the usual stream-alluvium. It is interesting to find, however, that in this lower part, terraces of flood-gravel reappear—at first, $\frac{1}{2}$ mile west of Union Mills, at about 100 feet above O.D. and not much above the level of the alluvium, but as usual with these terraces, falling less rapidly than the present valley-floor, and therefore gradually rising higher above it. The terrace is confined to the north bank at Union Mills, but sets in on the opposite side also below that place; and continues, with slight interruptions, to the

¹ "Isle of Man," p. 182.

² The six-inch Ordnance map is contoured at 100 feet intervals, up to 1,000 feet only, in the parishes of Braddan, Onchan, Marown, Lonan, and Santon, but not elsewhere in the Island.

outskirts of Douglas. Small pits have been opened upon it on both sides of the valley below Snugborough, revealing rough slaty gravel, loamy in places, with beds of sand and a sprinkling of foreign stones. It corresponds in all respects to, and is indeed apparently conterminous with the upper or Late-glacial terrace of the Glass valley above its confluence with the Dhoo (p. 456).

Since the level at which this flood-terrace sets in below the constriction so nearly corresponds to that of the flat floor of the valley above, where no terrace is seen, it seems highly probable that the alluvial flat between Union Mills and Ellerslie may itself represent the terrace, covered by more recent lacustrine or fluvial sediments.

Alluvium of the Southern Lowland.

In the low ground at the foot of the hills in the south of the Island many of the phenomena of the Curragh depression of the north are repeated, though on a smaller scale; and may be similarly explained as the result of the more rapid melting of the ice where impinged upon by land-drainage during the closing stages of the Glacial Period. Gravel platforms derived in part from the ice-sheet and in part from the hills, occupy much of the tract (pp. 470-2), while in the shallow depressions upon and around them later alluvial deposits have collected. Of these, the alluvial strips along the courses of the Silverburn and the Colby do not differ much from ordinary river-flats, though in places expanding to a greater breadth than such small streams could have produced under present conditions. On the plain between these rivers are two separate depressions which appear to have been in part occupied by standing water until artificially drained. The more easterly, about one-third of a square mile in extent, lies between Billown and *Bullakeigan*¹ (Sh. 16), a half-mile N.W. of Castletown, and has a floor of silty alluvial wash. This tract is shown as a lakelet on the old maps of the Island (p. 408). It drains to the sea at Poyll Vaaish; and Cumming mentions that in this vicinity, between Balladoole and *Scarlet House*, sand with marine shells was found, which he considered to represent the Raised Beach,² and to be probably continuous with a similar sand found in a neighbouring section to overlie blue marl with elk-remains. There is, however, no trace of marine conditions in the basin itself.

A gentle rise, covered with boulder-clay, intervenes between the above depression and the next basin about a mile farther west, where we find a low tract extending continuously from Arbory (Ballabeg of new Ordnance map) up to the Colby River south of Colby village. On Cumming's map ("Isle of Man," Pl. III.) the whole of this tract is shown as alluvium; but on the Survey map, after some hesitation, only the more easterly portion

¹ See p. 417, as to meaning of italics.

² Quart. Journ. Geol. Soc., vol. ii., p. 345.

of the depression, where the subsoil is a gravelly or silty wash, has been thus represented. There is no doubt that the whole tract has been at times submerged by floods, mainly from the overflow of the Colby; but the western portion does not appear to have been covered by any deposit which could be defined as true alluvium, the chief subsoil being a dark blue clayey earth, full of stones, mostly sub-angular fragments of slate and quartz, with a few rounded foreign pebbles. Though not strictly boulder-clay, this material seems to be essentially a re-arrangement of boulder-clay, probably by storm-wash. In most but not all cases the slate fragments have lost their glacial striæ, but have not been worn into rounded pebbles. This re-arrangement of the boulder-clay appears to have taken place after the deposition of the Glacial platform-gravels which border the hollow, but at a comparatively early stage in Late-glacial or Post-glacial times. To such material, in mapping the ground, I provisionally applied the term 'Colby Wash,' and thought that it might eventually prove necessary to represent its occurrences by a separate symbol or colour; but, though widely distributed wherever slaty drift formed flat ground whether at low or high levels (see p. 453, and p. 471), the material was not elsewhere found in so large a tract as the present instance, and was too limited in extent to indicate on the map. Indeed, as the 'Colby Wash' so nearly resembles the boulder clay in composition, and as the tracts in which it is developed are usually underlain and surrounded by that deposit, any separation between the original and modified condition of the clayey drift would have been difficult and of little practical utility. In this particular instance, however, it is not improbable that the 'Colby Wash' may in places cover fresh-water sediments of Late-glacial age equivalent to the elk-marls of the Ballaugh and Close-y-Garey sections (pp. 375, 384), though no direct evidence to this effect was obtained.

The greater part of the above-described depression drains through a little valley excavated in drift and limestone, which opens to the sea at Strandhall in the eastern corner of Bay ny Carrickey. At this place there is a gap in the limestone-scars on the foreshore just opposite the mouth of the brook, in which peat with trunks of trees is revealed when the beach-material is swept aside. This 'submerged forest' is mentioned by Macculloch¹ and Henslow² as having been exposed some time previously to their examination, but was not seen by them.

Cumming describes it as follows:—"In the autumn of 1845 I discovered, about a mile to the east of Mount Gawne, at the mouth of Strandhall Brook, betwixt high and low water, a bed of turf one foot thick, and the trunks of trees (oak, ash and fir); of which I counted eight in an erect position, and traced the roots of one (an oak) several feet in the stiff alluvial blue loam, which was evidently the subsoil upon which the trees grew. The

¹ "Western Isles," vol. ii., p. 527.

² "Trans. Geol. Soc.," vol. v., p. 500.

alluvium (which is not more than 3 feet thick) rests in part upon the nearly horizontal limestone and in part on a denuded bed of the boulder clay, and is situated at the opening towards the sea of one of the valleys of denudation. A few yards to the east and west of this submerged forest we have a raised beach of a recent period. It is possible at this particular spot to explain the phenomenon by supposing the bank driven back upon the land, and that formerly it intervened between the forest and the sea, and by a partial damming up of the water of the stream formed a swamp, and the alluvial deposit in which the turf and trees grew. However this may be, it is certain that this same alluvial marl is covered up in the neighbourhood by a recent marine formation."¹ In a footnote he adds, "It is singular that the trunk of an oak-tree which has been removed from the submerged forest at Strandhall exhibits upon its surface the marks of a hatchet." In another publication he states: "On removing the boulder clay into which the roots of these trees strike down, distinct glacial groovings may be noticed on the subjacent limestone."²

Cumming also obtained information indicating the existence of the old forest on the shores of the bay farther westward. Writing in 1848 he says, "Twenty-one years ago, according to the testimony which I have received from living witnesses, after a violent storm of three days the sands opposite Mount Gawne were swept away and discovered a vast number of trunks of trees, some standing upright, others laid prostrate towards the north, as if overthrown by some violent incursions of the sea. Nay, it has been further stated to me by those whom I am bound to believe, that the foundations of a primitive hut were laid bare, and that therein were some antique uncouth-looking instruments, once the property, it may be, of the primitive woodcutters."³

The presence of traces of man in the peat at Strandhall is also affirmed by Mr. J. M. Jeffcott of Castletown, who, in 1889, writes as follows:—"About eighteen years ago, and soon after the fragments of antlers [of the Irish elk, see p. 386] were found at Strandhall, a stream in that locality after a heavy fall of rain became swollen, overflowed its banks, and made a deep excavation in the sea-beach. Having visited this excavation on the day after its occurrence I found in the débris fragments of human skulls and other human bones. These were associated with the jawbone of a deer, believed by Professor Busk, to whom it was afterwards shown, to have been that of a red deer. The excavation made by the stream was, in some places, perhaps 6 feet deep. I afterwards caused the cavity to be further deepened to the extent of about four additional feet. On reaching this depth I discovered the recumbent trunk of a large pine. Close to the prostrate tree were quantities of oak leaves

¹ Quart. Journ. Geol. Soc., vol. ii., p. 344. See also "Isle of Man," p. 139.

² "Guide Book," p. 88.

³ "Isle of Man," p. 140.

pressed flatly together, and forming immense flakes from 8 to 10 inches thick. Some of the leaves in the interior of a flake still partially retained their green hue. In one of the flakes I found, between some leaves, elytra of beetles."¹

There was a small exposure of the peat in the upper part of the shore in 1892, during the present Survey, and some specimens of wood then collected were submitted to Mr. Clement Reid, who recognised, 'oak and a conifer, probably yew.'

While the position of this peat might be explained without postulating a change of level, by supposing, as Cumming suggested, that it was accumulated behind a protecting bank of shingle since swept aside, the hypothesis would fail to account for the channel excavated in the limestone, in which the peat lies. This channel, like instances of the same kind in other parts of the Island (p. 457, etc.), shows that some degree of elevation above present level must have occurred since Glacial times; and it is probable that the low-level forest grew during this period of elevation.

Though the relationship is not distinctly seen, the general run of the evidence strongly supports Cumming's idea that the adjacent Raised Beach is newer than the submerged forest; and if we accept the above-quoted evidence as to the presence of man in the Island during the formation of the peat-bed, it follows that depression succeeded by partial re-elevation has taken place since man's incoming. Moreover, as there is no reason to believe that Palæolithic man ever reached this region, and since it has already been shown (p. 403) that the Raised Beach may belong to the closing stages of the Neolithic period, it seems reasonable to conclude that these oscillations of level may have taken place during Neolithic times.

Another more irregular hollow occurs in the gravel platform $1\frac{1}{2}$ mile west of Colby, curving northward from the vicinity of Port St. Mary Railway Station, and extending past Trinity Church nearly to Bradda Mooar. This hollow, again, is only in part occupied by true alluvium, the stony 'Colby Wash' forming the subsoil in all except its central portion. The ridges of gravel which border the alluvium towards the head of the depression recall those around Close-y-Garey (p. 458). At *Cronk Mooar* (Sh. 16) a portion of one of these has been artificially shaped into a mound in prehistoric times.

Hill Peat.

The hill peat has not been separately shown on the published map, as its distribution is too ill-defined to be marked out by boundary lines; but where it attains exceptional thickness the word PEAT has been engraved. The higher ground of the central massif is more or less overspread with a peaty covering,

¹ Presidential address to the Isle of Man Nat. Hist. and Antiq. Soc., Mch. 1893, printed in *Yn Lioar Manninagh*, vol. i., p. 56.

varying from a single sod to a few feet in thickness, according to the shape of the surface. It is more prevalent in the slack between the principal or Snaefell hill-chain and the ridges to the westward than elsewhere, and is best developed where the slaty till has lodged. The northern slopes of Beinn-y-Phott, and particularly the long shoulder running out between Glen Crammag and the east fork of the Sulby River afford the most extended ground in which hill peat is comparatively thick (p. 449), while smaller tracts of thick peat are found at the gathering-ground of the drainage on the northern side of Snaefell; on the northern side of Colden; and to the westward of South Barrule. Though it is still accumulating in a few places, the climate nowadays does not seem so favourable to its growth as the past has been; and it has been further checked by the drainage of the hillsides for sheep farming.

The hill peat and that of the lowland hollows were once the chief fuel of the island, but their use is confined now to a few of the older farmers and cottagers in places remote from the ports. The turf seems in the past to have been largely obtained by paring the surface of the nearest hill, and only partly from excavation of the thicker deposits. There is no record of human or animal remains having been found in the hill peat, but it contains fragments of wood larger than the present natural growth of the hills.

CHAPTER XI.

DETAILED DESCRIPTION OF THE SUPERFICIAL DEPOSITS.

INTRODUCTION.

In describing the local details of the superficial deposits a similar course will be followed to that adopted for the solid rocks in Chapter IV. The land will be divided into three belts: (1) Northern, comprising the drift-plain; (2) Central: the hilly ground south of the drift-plain up to and including the Peel and Douglas valley; (3) Southern: the remaining portion of the Island south of that valley, with The Calf. The order of the descriptions within each division will be as before, first the coast-sections and afterwards the interior from west to east, in accordance with the numbering of the six-inch maps, while, at the same time, the physical boundaries will be cognised, as far as possible. The place-names in italics are those which appear on the six-inch, but not on the one-inch Ordnance maps.

NORTHERN DIVISION.

(Sheets 1, 2, 3, and parts of 4 and 5 of six-inch map.)

The arrangement of the Raised Beach at the Point of Ayre and its relation to the present beach have already been described (p. 402). Cumming stated that the lighthouse "at first closed upon high-water mark, has now a good piece of bank extending between it and the salt water."¹ That he was mistaken in this has been proved by our examination of the plans in the office of the Northern Lights Commissioners at Edinburgh, the old plan of 1815 when compared with the most recent plan of 1893 showing that between these dates the coast-line at the Point has undergone little or no alteration. The question as to the gain or loss of land at this point is of practical consequence in view of the possibility of other buildings being erected in connection with the working of the underlying salt deposits (p. 559).

The lighthouse obtains its water-supply from a well 25 feet deep, sunk in the Raised Beach within the enclosure. We were informed by the lighthouse-keeper that the water was rather brackish, but not more so in summer than in winter, and that the supply never failed. The section is said to exhibit 21 feet of shingle (Raised Beach) on 4 feet of clay (Glacial?). This water-supply taken along with that found in the experimental borings (p. 285) indicates that there is a steady percolation of the surface-rainfall inward through the shingle, probably augmented by a certain amount of rainage from the northern slopes of the Bride Hills.

There is a rapid tide along the northern side of the Point, with comparatively deep water (up to 11 fathoms) close inshore. Hence the present beach, composed of coarse shingle-ridges arranged in grand curves, is narrow and surprisingly steep considering the material; in one place an angle of slope of over 30° was noticed. The pebbles of the recent shingle are lenticular with those of the Raised Beach, and include few or no Manx rocks; the following are the chief ingredients of both: dark blue grey-sacke, grit, and quartzite; red and blue Carboniferous limestone; vein

¹ "Isle of Man," p. 224.

	Ft.	In.
Sand with stones [Raised Beach] - - -	15	0
Gravel - - - - -	27	0
Sand - - - - -	36	0
Clay - - - - -	34	0
Coarse gravel with sand and clay - - -	26	0
Sand - - - - -	73	8
Gravel - - - - -	0	8
St. Bees Sandstone (see p. 583).		
	212	4

As there was a general correspondence between the drifts of this boring and those of No. 4 which I had previously investigated in detail (see below), it was not thought necessary to wash and sift the samples which had been preserved. A well had been sunk to a depth of 16 feet in shingle, close to the shore, at 3 feet above high-water of spring tides, and yielded fresh water during low tide but slightly brackish water at high spring tides. The glacial 'sand' recorded in the above section was fine and pebbly, like that of No. 4 Boring, and yielded a few shell-fragments, including *Astarte sulcata*, *A. compressa*, *Mytilus*, *Turritella*, and *Planorbis*. The 'clay' was red, slightly pebbly, and not so sandy as that of No. 4. The pebbles shown to me exhibited the same general character as those of the previous boring; a few were faintly striated, but more were all-rounded, and two, which were said to have come from the base of the coarse gravel at a depth of 138 feet, were encrusted with nullipores.

Half a mile to the west of this boring, on the boundary between the parishes of Bride and Andreas, Mr. J. Todd, the engineer in charge, levelled line out carefully across the Ayre from an Ordnance bench-mark at 29 feet to the sandy inner part of the beach, and kindly allowed me to copy the figures. These show the elevation of the surface of bare shingle to range between 15.7 feet and 17.3 feet above O.D. at 150 to 300 yards from the present shore, while the ridge of blown sand nearer the sea-margin rises to 26.3 feet. The lowest of a series of levels on the Raised Beach further east, recorded on the six-inch Ordnance map, is 17 feet.

At Rue Point, where the coast-line takes a more southerly trend, the Knock-e-dooney Boring (No. 4), gave valuable information regarding the drifts, which were penetrated to their base. I was able to visit this boring from time to time during its progress (in 1895) and secured samples of the glacial deposits, which were afterwards washed and sifted, with the results given below. A well on the foreshore just above high water mark yielded good supply of perfectly fresh water in spite of the drought which prevailed at that time. The site is about 15 feet above O.D.

DRIFTS
BELOW SEA-
LEVEL AT
RUE POINT.

Section of the Glacial Deposits below sea-level in the (No. 4) Knock-e-dooney Boring near Rue Point, Isle of Man.

JOURNAL OF THE BORING

Published by Mr. J. Todd in "Yn Lloer Mauninagh," vol. III., pt. II., April, 1896.

	Ft.
Sand with stones - - - - -	16
Sand and gravel - - - - -	20
Soft sandy clay with fragments of coal - - - - -	40
Sandy clay - - - - -	25
Sand with small pieces of coal - - - - -	15
Sand - - - - -	34
Silt - - - - -	13
Gravel and clay - - - - -	10
St. Bees Sandstone (see p. 284).	173

DESCRIPTION OF SAMPLES EXAMINED.

The first 16 feet, and perhaps a little more, represent the Raised Beach.

At 50 feet. Clean sharp sand, with very small shell-fragments. On sifting, with sieve of $\frac{1}{4}$ inch mesh, only two or three small pebbles remained, and no shells.

At 93 to 95 feet. Fine warp or clay. No residue of any kind on sifting.

- At 107 feet. Fine silt. No residue except two crumbs of coal.
 At 117 feet. Clean sand. Only residue a few small quartz and lydite pebbles; no shells.
 At 130 feet. Silt. Only one small pebble remained after washing.
 At 132 feet. Rather clayey sand, with a few small pebbles of the usual drift type, and a much-worn fragment of *Balanus*.
 At 150 to 160 feet. Purple sandy clay, rather pebbly, with scattered shell-fragments.
 A large quantity of this material was washed, and among the shell-fragments, the following species were recognised:—

<i>Balanus</i> , sp. (abundant).	<i>Nucula</i> , sp.
<i>Astarte compressa</i> .	<i>Pecten</i> , sp.
<i>Astarte sulcata</i> .	<i>Mytilus</i> , sp.

These fragments had the angular character usual to shell-fragments in boulder-clays. Traces of the epidermis were preserved on some fragments of *Astarte*.

- At 165 to 170 feet. Silty sand. Not washed.
 At 173 feet. Gravel with worn shell-fragments.

<i>Balanus crenatus</i> ?	<i>Natica clausa</i> .
<i>Pectunculus glycymeris</i> .	<i>Fusus</i> , sp.
<i>Macra</i> , sp.	
<i>Mya</i> , sp.	

- At 174 feet. Red clayey gravel; mostly subangular fragments of St. Bees Sandstone, but a few erratic pebbles; one or two small bits of shell were found on washing

NOTES ON SOME PEBBLES OBTAINED FROM THE ABOVE SECTION.

		Diameter in inches.
At depth of about 165 feet.	Sub-angular striated fragment of Carboniferous Limestone	3½
	Somewhat subangular pebble of Ailsa Craig riebeckite-rock; encrusted with nullipores	1½
	Similar pebble of dark porphyry (Southern Uplands Silurian dyke-rock?); encrusted with nullipores	3
	Coarse reddish grit	2½
	Two glacially-striated pebbles of hard grit	about 2
	Fragments of basic igneous rocks (probably Scotch); porphyrites, etc.; also of Red Sandstone like St. Bees Sandstone.	
At and below 170 feet.	Red Sandstone and Carboniferous Limestone fragments more numerous than in above, but associated with porphyrites (Old Red?) and other non-local rocks. Most were rounded, but a few showed striations. The whole assemblage was that of a glacial gravel.	

No peaty material or other indication of a land surface was anywhere obtained in the boring,¹ nor was the general character of the deposits different from their character in cliff-sections. There was also no stratum found resembling the marine bed in the deeper part of No. 6 Boring (see p. 342). The foreign stones throughout were such as might have been gathered from any of the surface-sections; where shell-fragments occurred

¹ Mr. T. V. Holmes records the same fact in regard to the low-level drifts of North-west Cumberland, in the following passage:—'Borings, through the glacial drift into the underlying rocks near the Solway have never yet shown the existence of any inter-glacial vegetable deposit' Trans. Cumberland Assoc., part vi. (1881), p. 123 (foot-note).

The shells were all of species which occur in the cliff-sections, though the general assemblage was somewhat different, owing to the rarity or absence of *Turritella terebra* and some other gasteropods which are usually the commonest forms. But even in this respect the difference is not greater than is found between one part of the coast-section and another, where, as Mr. Kendall has observed, the species are very unequally distributed; which is the case also in the shelly drifts of East Yorkshire. The pebbles encrusted with nullipores have belonged to the same sea-bottom as the shells; the particularly interesting example from Ailsa Craig has been elsewhere discussed (p. 345).

Sand and gravel [Raised Beach]	-	-	-	-	Ft.
Muddy sand	-	-	-	-	16
Sand containing small pieces of coal	-	-	-	-	29
Sand	-	-	-	-	41
Clay containing small pieces of coal	-	-	-	-	20
Silt	-	-	-	-	15
St. Bees Sandstone (p. 579).	-	-	-	-	50
					171

Stratified gravel and sand, in places cemented into 'hard-pan,' 3 to 5 feet.
Contorted drift; consisting of sandy boulder-loam, stony clay, silty sand and clean sand, with gravel-streaks containing shell-fragments, chiefly *Tellina balthica*: a boulder of bluish flaggy grit, over 3 feet in diameter, occurred in this drift - - - - 20 to 40 feet.

The narrow strip of Raised Beach is continued south-westward to the mouth of the Lhen Valley (p. 373), and the most westerly and southerly of the deep borings (No. 3) was there sunk upon it (see p. 281). The drifts of this section are described as follows in the Journal of the boring. We have no further information regarding them:—

Sand and gravel [Raised Beach]	-	-	-	-	Ft.	In
Silt	-	-	-	-	12	
Grey sand	-	-	-	-	6	
Brown sand	-	-	-	-	48	
Sand and gravel	-	-	-	-	26	
Gravel	-	-	-	-	18	
Grey sand	-	-	-	-	8	
Gravel	-	-	-	-	9	
Silt	-	-	-	-	40	
					0	6
Carboniferous Limestone, 66 feet 10 inches.					167	6

On the eastern side of the Lhen there are two or more high terraces of gravel, which expand southward and merge into the drift-platform south of the mounded ground (p. 436). Its western side is encumbered with blown-sand that appears to have blocked up an old channel by which the Lhen-water escaped to the shore and forced the stream to find a new outlet 700 yards farther north. On a low mound of shingle, marked *Cronk y Bing* on the six-inch map (Sh. 2), round which the stream winds just before reaching the sea, I noticed a few flint chips; the tumulus of sand mentioned on p. 404 occurs on the rising ground half a mile S.W. of this place. The locality well deserves the attention of Manx archaeologists interested in the study of the physical conditions of the Island in Neolithic times.

For two miles S.W. from the Lhen there is a low persistent strip of blown-sand overgrown with bent-grass, about 100 yards wide, between the cliff and the shore, which appears to rest upon the prolongation of the Raised Beach. The cliff itself is also mantled with blown-sand, so that no section is visible except at one place, due west of *Cronkbreck* (at the shore-road marked on the one-inch map), where there is an old marl-pit showing a few feet of contorted stony loam and warp clay, with sand and silt. No erosion seems to be taking place on this part of the coast at present, until we reach Sartfield, three-quarters of a mile N. of Jurby Church, where the conditions suddenly change. Here the Raised Beach is cut out obliquely, and a freshly eroded cliff of drift is revealed, upon which the sea is making rapid inroads.

JURBY.

The first section traverses a hollow in the mounded drift 40 feet or more below the level of the surrounding ground, in which a little alluvium of some antiquity has accumulated. The section W.N.W. of Sartfield farmstead is as follows:—

	Ft.
Blown Sand, at cliff top - - - - -	about 8
Grey marly wash, peaty in places (Alluvium) - - - - -	4
Silty gravel - - - - -	2 to 4
Red clay and warp (contorted drift) - - - - -	about 25

To the south-westward of this hollow for 700 yards, the cliff is chiefly composed of red clay, partly stratified, with patches of gravelly wash on the top. A smaller hollow is then traversed, N.W. of Jurby Church, in which again a little alluvium has collected, with peaty layers showing impressions of reeds.

The fine cliff-sections of Jurby Head are too complicated and variable for ready description. In places they show an upper red pebbly loam or clay, 10 to 20 feet thick; passing down into sand, silt and warp clay with some gravel, 30 to 40 feet thick; which, in turn, passes down into a lower dull red or purple stony till containing large boulders and pebbly layers, and also shell fragments. But these divisions seem to possess no independence, and often become contorted and intermingled into an inseparable mass. There is, however, distinctly more clay and less sand and gravel in these sections than in the sections of the mounded ridges at Orrisdale Head, 2 miles farther south, and this agrees with the arrangement on the east coast (see Fig. 96, p. 355).

The cliff for $\frac{1}{2}$ mile south of Jurby Head has recently wasted more rapidly than any other part of the Manx coast, a strip from 30 to 50 yards wide having been lost in the twenty-eight years which had elapsed between the Ordnance Survey and my own examination. Owing to this waste, large boulders accumulate in numbers on the foreshore where not removed for road-metal; among the largest noticed were two of Galloway granite, respectively 6 feet by 6 ft. by 5 ft., and 8 ft. by 4 ft. by 2 ft.; and one of brecciated Carboniferous Limestone, 9 ft. by 8 ft. by 7 ft. Mr. Kendall commented on the prevalence of boulders of red sandstone in the lower clay in this locality, which he found in one section to comprise 15 per cent. of the stones; these, as he suggested, had probably been derived

from a concealed outcrop of beds of this character in the neighbourhood, an opinion since practically confirmed by the results of the deep borings.¹

About ten years ago a piece of the tusk of an elephant, 12 inches in length and 3 inches in diameter, was found in the cliff N.W. of Jurby Church.² It appears to be the only known occurrence of this vertebrate in the Manx drifts. Like the shells and encrusted pebbles, it has probably been transported from an older site.

On the southern side of Jurby Head the ground sinks gradually towards the hollow drained by the Killane River, the high-level or 80-ft. gravel-platform which is so well marked to the east and south-east of Jurby becoming more indefinite in approaching the coast, probably on account of the greater distance from the source of its material (p. 434). Though the upper margin or shore-line of this platform is represented in the cliff-section by a bed of coarse gravel 6 feet thick which thins out northward against the rising slope of clay, the gravel is not so continuous over the platform here as might be thought from its representation on the published map; being worn threadbare, so to speak, so that the underlying clay shows through in several places. The platform terminates southward in a steep bank which is one of the most sharply defined physical features of the drift-plain (p. 434). At the foot of this bank lies the lower terrace, 30 to 40 feet above sea-level, and through it the Killane River, a small brook slightly increased by artificial drainage, has excavated a little valley which breaks the cliff-line. Near the coast the low ground spreads thence southward for $\frac{1}{4}$ mile, and is then trenched a second time, at Ballakinnag, by the stream from Glen Dhoo. Beyond the mouth of this stream the mounded drifts rise up with a bold margin and continue into Orrisdale Head.

This stretch of low ground may have originated in a local modification and thinning of the upper part of drift, but the cliff-section shows that it must have been accentuated by later erosion. The chief constituent of its cliff-section is stratified warp-clay and silt, destitute of organic remains, resting on (the lower?) boulder clay, sometimes with traces of erosion and sometimes seemingly with a gradual passage. At the northern margin of the flat, near Ballateare, a platform of denudation has been scooped out in the warp, upon which lies an irregular layer of well-rolled current-bedded gravel which probably represents the shore-deposit of the Curragh lake at its second or Late-glacial stage. Before the Lhen channel was opened, it is possible that the lake may have had a westerly outflow in this quarter. The gravel dies out southward, or merges into fine material scarcely distinguishable from the underlying beds. A thin capping of sand, probably wind-drifted, completes the section.

Between the mouth of the Killane stream and Ballakinnag the blown sand at the cliff-top becomes thicker; and in one place, west of Crawyn, it contained indications of a Neolithic settlement at 4 feet below the surface, in the shape of numerous shards of coarse earthenware, flint-chips, and large stones marked by fire.

At the southern end of the low ground near Ballakinnag, a terrace has been scooped out of the warp, in connection with the drainage from Glen Dhoo, perhaps at the Raised Beach period, on which an alluvial deposit has accumulated, seen in the cliff-section to consist of 3 feet to 6 feet of whitish sandy marl, with a thin peaty layer below, and a base of washed gravel. The peat was searched for the arctic remains with negative result.

The fine cliff-sections south of Ballakinnag, ranging from 70 to about 140 feet in height, extend without a single gap for $2\frac{1}{2}$ miles to *Glen Trunk* on the S. side of Orrisdale Head. They intersect the western horn of the crescent of drift-mounds, not however by a direct cross-cut like the east coast section, but by an oblique traverse at a low angle. To the student of the

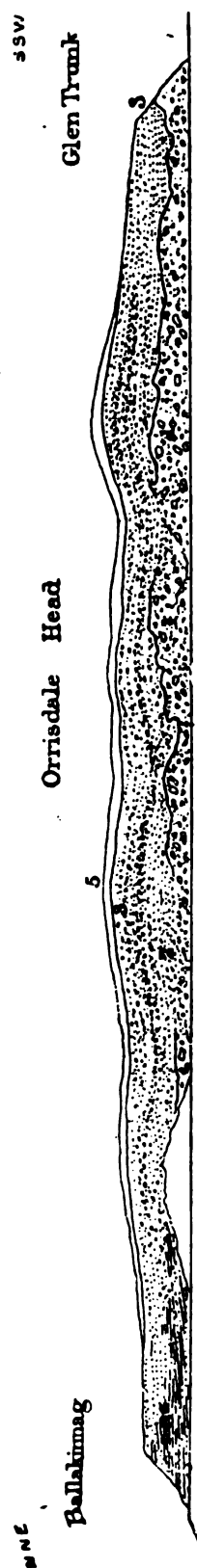
KILLANE
AND BALLAKINNAG

ORRISDALE
HEAD.

¹ Op. cit., p. 412.

² The fragment is at present (1898) in the possession of Mr. W. Kneale, of Douglas, whom I have to thank for allowing me to examine it.

FIG. 104. *Diagram of the cliffs between Ballakinnag and Glen Trunk, through Orrisdale Head. Length of section, 2½ miles; height, from 60 to 140 feet. Vertical scale much exaggerated.*



- 5 Blown sand.
- 3 Sand, laminated clay, and gravel, with an irregular seam of red pebbly clay.
- 3a Laminated silt and clay, with sand and fine gravel
- 2 Current-bedded bouldery gravel and sand
- 1 Sandy Boulder-clay.

shells or boulders of the Manx Extra-Insular drift these cliffs may be recommended as second in interest only to those of Point Cranstal.

The main facts of the section are shown in the accompanying diagram, Fig. 104.

As we enter the chain of mounds the warp, sand and fine gravel which at first occupy the whole section are replaced by coarse strongly current-bedded gravel, interspersed with thick beds of cleanly washed sand, mixed with a little warp and clay towards the top. The base of the cliff is for the most part obscured by talus, but for a mile to the southward of Ballakinnag seems to contain little or no boulder clay. Farther south a massive boulder-drift, presenting in places a vertical face and appearance like boulder-clay but of which the matrix is chiefly compressed sand, rises up from the shore and occupies the lower half of the section. The slate massif lies within a mile to the south-eastward of the section, and now begins to indicate its proximity by streaks of fine grey mud (somewhat like Fuller's earth, see p. 447), and by small slaty debris among the stratified beds, increasing in quantity and size as we go southward. Opposite Orrisdale the stratified beds in the mounds show a tendency to dip in a general way with the surface slope, but the features seem to have been accentuated by subsequent denudation. The section on the southern side of the Head has been given in Fig. 88, p. 339.

The shells are as usual, confined to the coarser stratified beds and boulder clay, and do not occur in the warp or silt; *Tellina balthica*, *Turritella terebra* and *Mytilus edulis* are the most plentiful, but probably most of the species recorded from the east coast might be found here also (see list, p. 473). Among the boulders and pebbles the following are more or less abundant:—Red sandstone, like St. Bees Sandstone, abundant; red calcareous sandstone with Carboniferous fossils (Peel series?); stained and brecciated Carboniferous Limestone, like that of No. 2 Boring; shale, probably Carboniferous; Permian brockram; grits, greywackes and conglomerates (from Southern Uplands) abundant; Galloway granites; Ailsa Craig riebeckite-rock; many varieties of porphyry, diabase, etc. A small collection of the rarer pebbles was examined by Mr. J. J. H. Teall, who noticed among them a granite and a quartz porphyry "probably Arran"; another "not unlike Garabal granite"; a greenish quartzite and a gneiss, "Highland rocks, probably Islay"; and a basalt, "Tertiary dyke, Arran, or Southern Uplands." Many of the limestone-pebbles show the borings of *Cliona* and *Saxicava rugosa*, and in one specimen which was collected the shells of the latter still remain in the cavities. Rolled bits of red clay are abundant in the coarser gravels, and denote the active erosion of parts of the series previously deposited.

The encroachment of the sea has not been quite so rapid on this strip of coast as at Jurby. The loss since the Ordnance map was made varies from about 30 yards near Ballakinnag to a few feet only near Orrisdale, but increases again southward. The Blown Sand which caps the cliff has previously been described (p. 404-5).

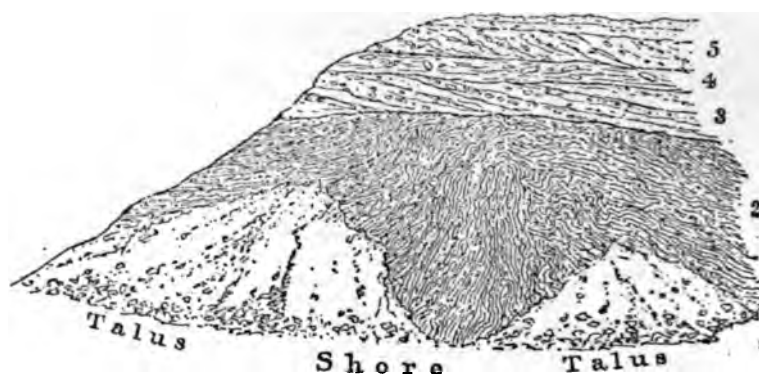
At Glen Trunk the cliff is notched down to shore-level by a narrow ravine through which the water from Bishop's Court and the Orrisdale basin reaches the sea; its sides are slipped and grassy and reveal no sections. The cliff immediately to the south of the gap shows, at the top, 10 feet of well-washed gravel containing much slate, apparently a Late-glacial flood-gravel from the hills. This thins out southward, but its place is soon taken by the similar but far more extensive gravel of the Kirkmichael platform. The drifts below this gravel resemble those on the northern side of the ravine; the section has been described and figured by Mr. Kendall, who records *Nassa serrata (reticosa)* and *Fusus Forbesi* among the shells he found here.

Half a mile farther south the cliff is again broken through, by *Glen Balleira* (Sheet 7). On the southern margin of this valley the following section was revealed in 1897, but as the cliff is wasting rapidly in this

¹ Op. cit., Fig. 4 of Plate.

L quarter, and the drifts are very variable, it may since have been modified. The point of chief interest is the strong unconformability between the contorted sand and warp series and the upper part of the drift. This structure though local is none the less noteworthy, as it affords another point of resemblance between the upper stony clay (4) and the Hessle Clay of East Yorkshire, which is often similarly placed and seems to have been "the residuum left behind on the melting of a sheet of ice charged with clay and stones."¹ The slaty gravel at the top belongs to the Kirkmichael platform above mentioned.

FIG. 105. *Cliff on the south side of Glen Balleira, Kirkmichael, height about 75 feet.*



Soil and sandy loam.

5 Current-bedded slaty platform-gravel, 8 feet thick.

4 Stony red clay, 4 feet thick.

3 Current-bedded sand and gravel.

2 Contorted warp and sand.

In the gravel platform 150 yards S. of *Glen Balleira*, a shallow depression, intersected by the cliff, shows 4 to 6 feet of grey alluvial marl and sandy loam, with peaty layers, resting on rolled slaty gravel. When traced inland, this hollow expands, and is broken into by the S. side of the above glen, giving partial sections in which alluvial material is seen in places as far eastward as the railway-crossing. The best exposure is at the top of the cut-road leading southward out of the glen to the farmstead of *Loghan ny Maidjey*, and is as follows:—

	Feet.
Soil : grey earthy loam with a few stones	1 to 2
Fine gravel of slate and quartz with a few foreign pebbles, streaked with yellow sand and pale silty sand with peaty stain : cross-bedded in places . .	7
Peat with small pebbles of slate and streaks of sand, passing into sand and fine gravel both above and below	1½
Probably more gravel like that above, hidden by grassy slope on side of road.	

¹ Drifts of Flamboro' Head. Quart. Journ. Geol. Soc., vol. xlvii., p. 424.

This alluvial hollow appears to mark the first stage of the excavation of *Glen Balliera*, and must be of some antiquity as it is 20 to 30 feet above the bottom of the present ravine. As peat with arctic remains was found in sinking a well on the gravel platform only 400 yards farther south (see page 374), some of the peat and silty sand from the above section was sent to Mr. J. Bennie for examination, but yielded nothing by which the climatic conditions could be determined. The following remains were recognised by Mr. Clement Reid in the washings of the peat :—

Menyanthes trifoliata.
Viola sp.
Carex, two or three sp.

Umbelliferous fruit (sp. indet.).
 Beetles (wing cases).

Immediately to the S. of Kirkmichael, the drift platform, narrowed to little over half a mile by the approach of the hills to the coast, is suddenly trenched on a larger scale than heretofore, by Glen Wyllin which forms a little cañon over 100 feet deep with an alluvial flat in the bottom and the remnants of a series of terraces, marking the progress of erosion, on its sides. These terraces are very clearly exhibited near the mouth of the valley, occurring at four different elevations, the highest being half-way up the slope ; they prove the persistence of subaerial conditions since the re-excavation of the valley commenced.

To the southward of this glen, the cliffs for three-quarters of a mile present excellent sections of the glacial deposits and the slaty platform-gravel, of which the following may be taken as a type :—

*Cliff-section 150 to 200 yards south of Glen Wyllin.*¹

		Feet.
	Top : Loamy Soil - - - - -	1½
Late - glacial Flood-gravel (thicker and coarser south- ward).	Roughish slaty gravel, sandy in places and at base - - - - -	1½
	Pale grey contorted loam with pebbly pockets and streaks, passing into—	3
	Irregularly bedded sand and gravel with some clayey layers ; the gravel smaller and less slaty than top bed - - - - -	about 10
	Upper Boulder Clay †	
	Band of red sandy clay with rounded stones - - - - -	3 to 6
Intermediate Stratified Series.	Irregular ripple-marked sand with some pebbles, and streaks of laminated clay	about 12
	Greenish-grey contorted loam and unctuous clay with streaks of sand and gravel - - - - -	3 to 6
	Small dark gravel and sand, with shell- fragments - - - - -	20 to 30
	Red sandy clay with stones and shell- fragments ; interstratified with gravel at top - - - - -	6
	Interval concealed by talus	about 10
Lower Boulder Clay.	Purple boulder clay with shells: at foot of cliff - - - - -	about 6
	Height of cliff about	90
	<i>Exposed on the foreshore.</i>	
	Red pebbly clay, and indurated sand (scrablag) crowded with broken shells; contorted and mixed together.	

¹ An adjacent and similar section has been figured by Mr. Kendall, op. cit., Fig. 5.

The greenish grey silty clay about 35 feet from the top of this section seems to be the same material as the "Fuller's earth" of the upper reaches of Glen Wyllin (p. 447). The shelly drift below the foot of the cliff was well exposed on the foreshore in 1895, and proved richer in shells than any other portion of the Manx drift known to me except that passed through in Boring No. 6 (p. 342); it appeared to be a strip of the old sea bottom, dragged up and only partly incorporated with the boulder clay; the most abundant species was *Turritella terebra*, but there were also many others. Mr. Kendall found a similar strip, containing however an altogether different assemblage of species, at Point Cranstal on the east coast (op. cit., p. 431). With such material in the body of the ice-sheet, the presence of shells in the gravels deposited when it melted is easy to understand.

As the solid hills approach nearer the coast, not only does the slaty gravel at the top of the section become coarser and thicker, but slaty debris is also found abundantly in all the gravels. At *Glen Mooar* (Sheet 6), a wide gap in the cliff $\frac{1}{2}$ mile S. of Glen Wyllin, the top gravel is 15 feet thick; but a few hundred yards inland on the plateau it is at least twice this thickness, and slate fragments, often subangular, constitute over 95 per cent. of the pebbles, the remainder being derived from the drift. The old terraces of erosion are almost as conspicuous at the mouth of this glen as in Glen Wyllin; the principal ones are respectively 6 feet; 10 ft.; and 20 ft. above the present stream. Slate crops up in the bottom of the valley 300 yards inland, and rises above the surface of the drift-plateau 50 or 60 yards farther east, close to the high-road. Between the slate outcrop and the shore there is an excellent section of the glacial deposits in the south bank of the valley, which has been figured and described both by Mr. Horne¹ and Mr. Kendall² as illustrating the relation between the local and foreign drift. It shows, at the base, 15 feet of red stony clay and sand of the usual 'extra insular' character, both clay and sand containing shells; covered by 20 feet of dark grey slaty till, made up almost, but not altogether, of insular material; and about 10 feet of slaty platform-gravel and sand at the top.

Similar features, though with some difference of detail, are repeated in the cliff-section 300 yards farther south, where the slate first comes out on the coast; and immediately beyond, we reach the section at Gob ny Creggan Glassey discussed and figured on a previous page (p. 348. Figs. 92, 93).

The loss of land between Kirkmichael and Glen Mooar since the Ordnance survey ranges, as a rule, between 20 and 30 yards. From the point where the slate enters the cliff, to the southern extremity of the Island, the rate of erosion is so slow as to be of no practical consequence.

Eastern Side of the Northern Plain.

The coast-sections on the eastern side of the drift-plain are not so extended as those on the west, and owing to the less rapid rate of marine erosion are more frequently obscured by talus; but at Point Cranstal they comprise one of the grandest cliffs of drift in the British Islands. The general character of the deposits has been indicated in the diagram, Fig. 96, to which the additional details given below may serve as explanation.

CRANSTAL.

Starting at Portcranstal, on the southern margin of the Raised Beach, we have at first a comparatively low cliff, composed chiefly of stratified warp, sand and clay, locally contorted. The sections for some distance are grassy and obscure, but become bolder half mile south of Portcranstal, where they are composed from bottom to top (70 to 90 feet) of massive red boulder-loam, with a locally varying proportion of sand to clay; and this material is only obscurely bedded. Stratified drifts then reappear in the lower half of the cliff; and afterwards in the middle portion, dividing the boulder-loam into two parts. As we draw near the Bride Hills the stratified deposits assume increasing importance, and include lenticular masses of coarse current-bedded gravel, probably marking old river channels; as

¹ Trans. Edinburgh Geol. Soc., vol. ii., pt. iii., Fig. 11, p. 21.

² Op. cit., Fig. 7, and p. 413.

well as much laminated clay, warp and silt, often passing into and confusedly intermingled with stony loam and boulder-clay. The whole series, indeed, bears much resemblance to the 'Contorted Drift' of the Norfolk coast. Shell-fragments are present, but in smaller numbers than in the sections farther south. The gravels are in places full of round washed lumps of clay, and the sands often contain streaks of coaly matter.

Just before rising into the steep slope of *Cronk-ny-Irey-laa* (267 ft.; the name is now obsolete), the cliff sinks to 50 or 60 feet above O.D. in a broad shallow depression of Late-glacial erosion, which drains away from the coast into Lough Cranstal (p. 418). In the floor of this hollow a few feet of washed gravel overlie the contorted-drifts. The ground then rises to over 200 feet, blown sand 4 to 6 feet thick forming the top of the section (p. 405). The rise appears to be due partly to the thickening and partly to the crumpling up of stratified drift, the beds in many places being now at a far steeper angle than the angle of rest of such material during deposition. This great section contains little or no boulder-clay, the chief constituents being red and purple laminated clay, warp and sand, without fossils; and thick irregular masses of current-bedded gravel and sand, containing many worn and fragmentary shells often locally cemented into 'hard-pan' ('*scrablag*' of the Manx) which where the beds are tilted weathers out into picturesque reefs and spires above the crumbling slopes. Where the beds are horizontal, the cemented material often takes the form of long flattened rods, generally with the long axis approximately N. 30 W.—S. 30 E., indicating the direction of underground percolation of water; in some instances it occurs along joint faces, and has then a curious dyke-like aspect. Blocks of this material accumulate in such abundance at the foot of the cliff that they have been largely used for dry-walling; the lime which constitutes the cement comes from the solution of shells and limestone pebbles; it is redeposited wherever the underground drainage is checked.¹

POINT
CRANSTAL
(BETTER
KNOWN AS
SHELLAG).

On the southern side of the hill another deep hollow occurs, its bottom like the last-described, containing a little flood-gravel and falling away inland (see map, Fig. 97). The long talus slopes of the cliff to the southward of this place constitute the favourite collecting ground for the shells of the drift (see list, p. 473). The deposits here assume a more regular stratification, and contain less coarse material as we pass to the southern side of the chain of mounds. At the edge of the platform, immediately south of the mounds, we find the section as figured on p. 339 (Fig. 88). South of *Kionlough* the cliffs are sloped and grassy, and it is only at intervals that their structure is revealed; but there seems to be a general tendency for the gravels to die out, leaving only the fine stratified silt and warp; with a band of red stony clay or loam in the upper part, and tougher boulder-clay at the base. At Sea-view we descend rather sharply from the upper platform, at 90 to 100 feet above O.D., to the second platform at 55 to 65 feet (Fig. 96, p. 355), but this definite terrace-feature fades away within a short distance inland (p. 436). It is noteworthy that the natural drainage of a little alluvial hollow within 200 yards of the coast at this place follows a winding channel inland to the eastern curragh and thence to the Sulby River, flowing 5 miles before it reaches the sea at Ramsey.

SEAVIEW
(DOG-MIL
TO RAMS)

Two hundred yards S. of Sea-view the cliff showed the following section:—

	Feet.
At the top; irregular gravel, yellow sand and pale silty sand: = Platform-gravel	3 to 8
Tough red pebbly clay, semi-stratified; top uneven; contains shell fragments: = Upper Boulder clay	2 to 8
Stratified sand, silt and warp, locally contorted	20 to 30
Base hidden; probably red clay.	

¹ See Henslow, Trans Geol. Soc., vol. v., p. 495.

RAMSEY.

In the mile intervening between this section and Ramsey the sea is debarred from the foot of the cliff by a low narrow terrace rising only a few feet above high-water mark. It is not clear whether this is a storm-beach of recent times slightly raised by blown-sand, or whether it represents the Raised Beach. It merges at North Ramsey into the shingle-bar of *The Mooragh*, behind which lay the old course of the Sulby River before its present direct outfall through Ramsey Harbour was opened. By the erection of a sea-wall the bar has been reclaimed and converted into building ground, and the depression behind it into a park. The section in the old cliff behind *The Mooragh* has been described and figured by Mr. Kendall¹; it resembles that given above. In an excavation for a sewer at the northern end of the Mooragh, described by Dr. Tellet and Mr. Kermode, numerous shells were found in a bed of boulder-clay 12 to 15 feet thick; and Dr. Tellet notes that two examples of *Tellina balthica*, embedded in hard grey-brown boulder-clay, had their valves united and closed, and full of a white silicious sand in which were some foraminifera.²

In the foundations for the Swing-bridge across Ramsey Harbour the following section was obtained, which shows the composition of the drift below sea-level:—

	Ft.	in.
Sand and beach-shingle - - - - -	7	0
Stiff red clay (calcareous) - - - - -	4	0
Soft silty sand - - - - -	14	0
Stiff red clay - - - - -	1	9
Soft silty sand - - - - -	5	9
Stiff red clay - - - - -	2	6
Hard compact sand and shingle - - - - -	15	6
Total - - - - -	50	6

The low part of Ramsey on the southern side of the Harbour stands on a wedge of Raised Beach which has been preserved in the recess at the estuary of the river. The ancient drift-cliff still forms a steep bank behind Waterloo Road, gradually becoming less marked and merging into the valley-slope when traced westward.

Sea-defences conceal the section south of the town until we reach Ballure Glen, though tough red stony clay containing shell-fragments is sometimes visible in the slope above the wall south of the Promenade Pier, and also on the foreshore when the sand is washed aside. The excellent section between Ballure Glen and the slate-cliffs has already been described and figured (Fig. 91, p. 346).

PRELIMINARY NOTE ON INTERIOR OF THE NORTHERN PLAIN.

The difficulty often found in the conventional separation of glacial deposits into 'boulder-clay,' and 'sand and gravel,' makes itself keenly felt in mapping this area. On the one hand the material which from a geologist's standpoint is 'boulder-clay' is frequently so sandy or stony as to yield a light loose soil; while on the other hand the laminated clay and warp which form an important constituent of the stratified portion of the series, though necessarily taken as part of the 'sand and gravel' drift, make stiff clay-land at the surface. A thin superficial coating of sand, either wind-drifted or rain-washed, is also very prevalent on flat ground, even when the subsoil is clay. Under these conditions the representation of the divisions, especially on the small-scale map, must sometimes be misleading as to the character of the soil and must not be too strictly interpreted. As a general rule, however, the clay-land has been shown on

¹ Op. cit., Fig. 1 and p. 410.

² Kermode, *Yn Lioar Manninagh*, vol. i., No. 4, p. 96, and Tellet, *Trans. Manx. Geol. Soc.*, 1889-90, p. 6.

the map by the 'boulder-clay' colour, and the light land by the 'sand and gravel' colour, irrespective of technical nomenclature, wherever this could be done without violence to the geological interpretation. Some deviation from this rule will be duly noted in subsequent pages.

For information as to the internal structure of the drifts, it is, of course, to the coast-sections that we should chiefly apply ourselves. But as an object-lesson in the development of a drainage system, the interior of the plain is of great interest. The obliteration of all pre-existing topography therein by the glacial deposits; and the ease with which new channels of superimposed drainage have been carved out in the soft materials, to be afterwards partially or completely abandoned under changed conditions; have given rise to phenomena which might serve as an epitome of the history of the physiographic evolution of many a larger and more enduring tract; and with the increased attention now given to these studies, the area may be recommended as an enticing field for any investigator with leisure to follow up the subject in detail.

For our present purpose, the district will be described under the following sub-headings:—the Bride Hills and their westerly prolongation up to the Lhen; the Jurby Platform, west of the Lhen and north of Killane river; the Andreas Platform, between the Lhen and the east coast; and the Curragh Basin.

Bride Hills.

A westerly segment of the moundy ridge, separated from the Bride Hills proper by a broad shallow depression, runs E.N.E. from the Lhen to Knock-e-Dooney, rising 50 or 60 feet above the plateau. Its easterly portion shows principally sand and gravel at the surface; but farther west a more compact drift with pebbles and boulders, occasionally well glaciated, set in a sandy matrix, is seen in the road-cuttings crossing the ridge. One of these, at Ballamacskelly, yielded an unusually large subangular fragment of the Ailsa Craig riebeckite-rock, 8 inches in diameter, being the largest piece observed during our survey. In places this boulder-drift is mingled with more clay, and has then been dug for 'marling,' having apparently been preferred for this purpose to the stiffer clays. An old marl-pit on the north side of the ridge, 350 yards W. of Knock-e-Dooney farmstead, showed (in 1895) a contorted bed of fine gravel full of shells, under or among red stony loam. The following shells were collected, and longer search would no doubt have made additions to the list: *Turritella terebra* (very common); *Murex erinaceus*; *Trophon clathratus*; *Purpura lapillus*; *Pleurotoma turricula*; *Fusus*, sp.; *Astarte sulcata*; *Tellina balthica*; *Maclura solida*; *Corbula gibba*; *Mytilus* sp.; *Pecten* sp.; *Balanus* sp.

The strip of lower ground to the northward, between the ridge and the old cliff edging the Raised Beach, is underlain chiefly by boulder-loam, modified in places by a little blown sand on the surface. There are numerous old marl-pits in this tract, and some large boulders of granite, diorite, etc., in the fences. From the S.W. end of the ridge the ground falls away to the Lhen valley in terraces which are more or less gravelly; the lowest is a narrow bank which belongs to a late stage in the excavation of the valley, but the two higher are broad sloping platforms which cannot be assigned to ordinary fluvial action; the highest probably represents the high-level Jurby platform, and the second the Late-glacial Curragh Lake terrace. They are broken through and destroyed on the east by a little winding glen which runs parallel to the southern side of the ridge, and drains in part from a small irregular alluvial hollow at Ballacunner, and in part by artificial trenches from a broader depression N. of Andreas. The walls of an old cottage on the lower terrace at Ballaclucas (Sheet 2), contained (in 1894) a good collection of large boulders, among which were a mica-trap and a coarse granite with large pink feldspars. Chipped flints are rather abundant near the margin of the Lhen, not only in this locality but throughout its course. Where the gravelly terraces fade out, the low slopes

BALLA-
MACSKELL
(BALLA-
THONA OF
NEW
ORDNANCE
MAP.)

bordering the ridge on the south become more loamy, and the difference in composition between the low ground and the neighbouring high ground is scarcely perceptible; they have, however, been differently coloured on the map, for the sake of defining the shape of the ridge.

The depression between the eastern termination of the above ridge at Knock-e-Dooney and the western termination of the main chain of the Bride Hills near Smeale, has been referred to as a possible outlet from the lake waters at their higher stage (p. 372). It has a breadth of about half a mile, and an elevation of 75 to 80 feet above sea level; it is covered with gravelly loam resting on the usual mixed boulder-drift. Part of its floor is occupied by a chain of curious shallow depressions, which form natural ponds partly dry in the summer. The most southerly of these, *Lagagh Mooar* (Sh. 3), is the largest, being 400 yards long by 250 yards broad; in its midst there rises an artificial mound, *The Buggane*, marked *Fort* on the ordnance map. The smaller but deeper hollow of *Curragh-y-cowle* lying 200 yards farther north is connected with the former by a narrow strip of alluvium, on which coarsely chipped flints of larger size than those usually found in the island are peculiarly abundant. Another pond, near Ballakinnag 300 yards farther north, appears to have drained originally to *Curragh-y-cowle*, thence to *Lagagh*, and westward to the Lhen; but afterwards the whole system was tapped by a little valley, indicated by a strip of alluvium on the geological map, falling north-eastward to the Raised Reach opposite Smeale. Like the depressions at about the same elevation on the gravel platform at Ballaugh in which the elk-remains were found (p. 375), these hollows may possibly be due to eddies in the current entering or leaving the old lake. Their mode of occurrence separates them from the 'kettle-holes' often found among morainic drift, as they are confined to the terraces, and do not occur among the mounds. Among the numerous boulders in and around the buildings of this locality is one of unusual character, possibly from the Lower Silurian Volcanic series of the Lake District, measuring 4 feet by 3 feet by 2 feet, at the gateway of the old cottage on the north side of the high road immediately west of the alluvial hollow between *Curragh-y-cowle* and *Lagagh Mooar*.

N. OF
EAS. The termination of the Bride Hills on the eastern side of the depression above described is more gradual than that of the opposite ridge; and is, indeed, ill-defined. Its indefiniteness is largely due to the complicated effects of ancient flood-erosion, which has trenched the hills first in one direction and afterwards in another nearly at right angles to the first. The oldest system is represented by two broad troughs running almost parallel to the hill-range, or from east to west nearly; the more northerly has a course of about 1½ miles, starting east of Thurot Cottage, passing to the south of Smeale Beg and opening near Knock-e-nean into the above-described depression; the more southerly, starting near West Kimmeragh (see plan, Fig. 97, p. 375), has probably once continued to Johnnea, but has had its southern side broken away east of Braust. These channels were probably abandoned from some change in the glacial lake-level; and a new system, draining southward more or less at right angles to the ridge, was then initiated, which carved out deeper and narrow valleys and soon truncated the older hollows. The western end of the hills is from this cause not only notched and broken but likewise obscured by flood-fans of gravel.

As mentioned in a previous description (p. 358), some of the transverse valleys have trenched the ridge from side to side. In these cases their floors have a long gradual slope southward and a shorter sharper gradient northward from a low col lying to the north of the centre of the hill-range, this northward slope apparently marking reversed drainage on a small scale, which asserted itself when the margin of the ice-sheet had shrunk back from the ridge. The high-road crossing the ridge north-eastward from Andreas past Thurot Cottage is carried through one of these valleys; the Ordnance levels along it show a rise of from 90 feet above O.D. on the gravel platform near Braust to 238 feet at the col a mile farther north, and a fall thence northward to 130 feet in the next 600 yards, the valley-slopes rising steeply 50 to 60 feet above the road in the pass. A

mile farther east another similar valley, which may be taken as the typical example, has been utilised for a branch from the Bride highroad leading past *Lambhill* to Cranstal (see plan Fig. 97, p. 357); the broad inclined floor of this valley spreads out into the sand and gravel delta south of East Kimmeragh, and the steep, well-preserved slopes on both sides rise 60 to 80 feet above it,—eloquent tokens of the former flow of a considerable stream, and in striking disparity with the present aridity of the loose gravelly soil of the valley. Another example, not so deeply notched on the crest, leads across from Ballavarkish to Ballacottier, less than $\frac{1}{4}$ mile farther east; this is tributary to a broad depression of the older type, 150 to 250 yards wide, which has its down-slope inland and runs east and west, between Ballavarkish and Ballavair, until beheaded by the coast-line S. of Point Cranstal, as mentioned on p. 429.

The ramifying system of minor valleys, running in every direction among the hills and falling southward, needs no description beyond that already given (p. 356 and Figs. 95, 97). Not only are all these valleys without present drainage, but they have also been in this state since the time when the high-level gravel-platform was spread out at their mouths, as this platform is in no case trenched where they emerge upon it.

In composition, the Bride Hills are evidently much the same throughout as in the coast-section at Point Cranstal (p. 355). Sand and gravel, the latter sometimes coarse and bouldery, predominate between the summit and the southern margin, but are interspersed with patches of boulder-loam and stratified clay, into which marl-pits have been opened; and on the northern slopes boulder-loam and clay is the prevalent constituent. The general arrangement confirms the evidence of the coast-section in showing that though the hills have been modified by denudation, they are essentially a feature of original accumulation. Large boulders are plentiful in both the stratified and unstratified portions; and are being constantly dug out to prevent them impeding the plough (all except the steepest slopes being under cultivation), and because of their general utility for road-mending and building in this otherwise stoneless country. Those of Galloway granite are the most abundant, and may be seen in profusion in the fences and buildings, as for instance in Bride Church; the larger blocks of this rock were formerly often shaped into agricultural rollers. A fine granite boulder measuring 9 feet by 4 feet by 5 feet was noticed in an old marl-pit $\frac{1}{4}$ mile N.E. of Braust. Lower Silurian grit from the Southern Uplands is also abundant, of which a good example, 8 feet by 6 feet by 6 feet, which had been split by blasting but not removed, lay near the eastern fence of a field 400 yards S. by E. of Ballakillee.¹

The altitude of the highest point of the Bride Hills is not given on the Ordnance map, but the Admiralty chart gives 310 feet as the height of the summit of Ballacash Hill, one mile W. of Bride Church.

The lower drift-ground to the N. of the Bride Hills, abruptly truncated northward by the old cliff overlooking the Raised Beach, is $1\frac{1}{2}$ miles in width near the E. coast, but narrows to $\frac{1}{4}$ mile westward. It forms a gentle slope falling northward, but is broken by the long irregular hollow of Lough Cranstal, which has once held a small lake but is now drained to the condition of a waterlogged flat. Into this hollow from the northern side of the hills run little shallow valleys, some of which are now dry, while others still retain rivulets in artificial gutters. The alluvium of the hollow is merely a thin sandy wash derived from the drifts, with a peaty surface in places; but there are indications that the depression was originally excavated by a stream strong enough to transport gravel and form terraces. There is a predominance of rather stiff soil on the slope, varying from clay-land to sandy stony loam, and the greater part has therefore been coloured on the map as 'boulder clay.'

¹ For details of some of these boulders, see Rev. S. N. Harrison's lists in Reports of Erratic Blocks Committee, British Assoc. Reps., for 1891-2-3. and Yn Lioar Manninagh, vol. 1., no. 11, p. 375.

but the numerous old marl-pits show that while in some places the subsoil is true boulder-drift, in others it is stratified clay or warp without stones, and in both cases often mixed confusedly with patches of sand and gravel. One or two localities in which sand and gravel attain ascendancy have been indicated on the map. The absence of the gravel delta-platforms on this side of the hills, which are so conspicuous on the opposite side, shows that the drainage conditions have been very different; and the whole evidence sustains the view already put forward (p. 358) that the hills have accumulated as a moraine along the margin of the ice-sheet during a pause in its retreat, and have been deeply trenched by heavy floods pouring across them from the ice into Lake Andreas.

The Jurby Platform.

JBV.

The shape and character of the tract bordering the coast in the parish of Jurby suggest that higher land, forming a link between the Orrisdale mounds and those near Ballamackskelly, has been destroyed by the sea. The ground still for the most part rises towards the cliff; and high-lying mounded gravel north of Sartfield probably marks the inner slope of a vanished ridge; while the elevated clayey strip to the southward, in which are several old marl-pits, may indicate a further segment of the ridge. To the eastward lies the great gravel platform, stretching N. and S. for two miles from the Ballaghaie to Ballateare, and E. and W. for $2\frac{1}{2}$ miles from Jurby to the Lhen valley. The average altitude of this platform is about 80 feet above O.D.; it rises to 90 feet in the vicinity of Sartfield, where the gravel is probably thickest; and falls to 70 feet towards its southern boundary and towards the Lhen, where the material scantily covers the underlying beds. The distribution of the gravel with a generally even surface over a tract of this extent precludes ordinary stream action; and the trend of the whole evidence, as previously stated, is against the possibility of marine agency; while the hypothesis of the former presence of a lake appears to explain satisfactorily all the facts. From the steady thickening and increasing coarseness of the gravel towards the north-west, we may be tolerably certain that the material was brought down into the lake from that quarter; and of this we have confirmatory evidence inasmuch as the surface of the platform becomes undulating, and rises near Jurby School-house into low ridges of bouldery gravel striking W.N.W. to E.S.E. and then merges insensibly into the gravelly mounds near Sartfield.

In the Manx agricultural districts the houses are generally scattered broadcast over the land; but on this platform, as the map shows, they are rare, on account of the lack of water near the surface, a condition to which Manx farmers are not accustomed (see p. 570). The farmsteads are therefore ranked along its southern edge where water is given out at an under-lying clay-bed, and in its eastern part where the gravel is thin. A well at the N.E. corner of a field 650 yards S. of Loughan is said to have passed through 20 feet of sand and gravel, to clay.

The north-eastern part of the plateau is not so regular in composition and simple in structure as the south-western, being broken by little valleys sloping eastward or south-eastward towards the Lhen, and by tracts in which there is scarcely sufficient covering of silty sand and fine gravel to conceal the underlying clay. Though on the published map the only part of this ground coloured as clay is a lenticular strip between Ballachrink and Ballachonley, there are other tracts in which, while the soil itself is sandy or gravelly, it is underlain by clay within a foot or two of the surface; one such area occurs N.W. of Rhendhoo and another round Loughan; and even farther in the interior of the plateau, about half mile S.E. of Jurby Church, red clayey soil unexpectedly reveals itself. The gravels have probably been deposited on an uneven surface of clay; and their thinning away towards the east and north-east, where the ground sinks to 70 feet, denotes the position of the outskirts of the delta.

The longest of the above-mentioned channels cutting the platform starts from a little boggy basin at Loughcroute, which has a margin of sandy

alluvial wash with some peat in the middle, and seems to be of the same character as those around Lagagh Mooar previously described. The trench, a mile in length, with the present drainage trickling in an artificial gutter in its midst, runs south-eastward to the Curragh end of the Lhen Valley, passing through another small basin on the way. Several shorter valleys, also draining to the Lhen, trench the platform to the north of this; while to the westward are others, of which those of *Ballachurry* (Sh. 4) and *Berrag* (the latter with a small peat bog in its floor) are the largest, falling southward to the lower terrace bordering the Curragh. From the manner in which the last-mentioned valleys terminate upon this terrace we may judge that they were excavated at the period when the lake had subsided to its lower or 40 ft. level.

The sharp feature which marks the descent from the upper platform to the lower platform has been noticed in describing the western coast-section (p. 423). For three miles eastward from the coast it continues to form a regular bank 30 or 40 feet high, broken here and there by the above-mentioned little valleys, and diversified by the trees and gardens surrounding the chain of substantial farmsteads which are placed upon it. Swinging northward, the feature then makes the western bank of the Lhen Valley, and in this guise sweeps round the platform to the coast again. That it is throughout its course a denudation-feature there can be no doubt. In the Lhen Valley it has been carved out by fluvial action, but elsewhere apparently by lacustrine agency. Almost everywhere this bank is in part composed of clay, sometimes stony, but oftener of the stratified warpy kind. Usually the clay is overlain, and sometimes also underlain, by sand and gravel; so persistent is this arrangement that the different beds might almost have been shown on the map, if the scale would have permitted, with regular outcrops, just as one might show an equivalent thickness of horizontal 'solid' strata. Such regularity is very unusual in the drift-sections of the Island.

The Lhen valley, of which the general characters have previously been described (p. 373), forms the boundary between the parishes of Andreas and Jurby. The drain cut about 250 years ago¹ along the middle of the broad flat valley-floor now carries a steady flow of water from the northern edge of the Curragh, but previous to its excavation there does not appear to have been any distinct water-course in the glen; and it is probably because of the former absence of a definite channel that the parish-boundary runs along the foot of the western bank instead of dividing the valley between the two parishes. In many places there is a thin superficial layer of peat in the bottom, which here and there has been cut for fuel; but the flatness of the floor, even where widest (over 300 yards), appears to have been due to the broad shallow character of the stream by which the valley was excavated and not to a later infilling by boggy growth, as within three or four feet of the surface the artificial trench seems to possess a firm bottom of washed sand (sometimes rather peaty) and fine gravel throughout its length. At the great bend near Ballachrink where the course changes from northerly to westerly, the valley-slopes exhibit a steep bluff on one side with a more broken and gradual descent on the other, such as is usual in stream-banks where erosion has recently been in active progress. Where it leaves the Curragh, the valley-bottom is 30 feet above O.D., and is not more than a foot or two lower opposite Ballachrink 1½ miles farther north. Low discontinuous terraces of sand and gravel occur here and there within the Lhen, chiefly as small deltas near the confluence of subsidiary valleys; but on the whole these marks of progressive erosion are surprisingly inconspicuous. The presence of chipped flints on these banks, and of a so-called 'fort' or crannog-mound in the bottom opposite Ballachrink (Sheet 2), indicate a pre-Neolithic age for the excavation of the valley. As previously explained (p. 373), the glen probably began in Late-glacial times as a channel for water flowing southward from the melting ice, but afterwards acted as the principal northward outlet of Lake Andreas;

¹ See Moore's "History of the Isle of Man" vol. ii., p. 921.

under the latter condition it would be likely to carry floods filling the valley from side to side at certain seasons, and at other seasons to be almost dry. The absence of slaty *débris* shows that the streams flowing northward from the mountains into the lake left their load of detritus in the basin before passing out through the Lhen.

The Andreas Platform.

The ground between the Lhen valley and the E. coast constitutes an uneven platform falling away southward from an altitude of 100 feet above O.D. near the Bride Hills to about 30 feet along the Curragh margin. A terraced arrangement is exhibited to a slight extent near the E. coast, but is scarcely recognisable over the greater part of this tract; and as there is much variability and indefiniteness in the character of the drift at the surface, the rendering of the area on the geological map is necessarily patchy, and somewhat confused.

In the west, along the eastern margin of the Lhen, there seem to be traces of the prolongation of the Jurby gravel-platform between Ballamagagh and Gylcaugh; but the gravel rapidly fades out eastward into rather uneven clayey ground. In the N.E. a broad flat gravel-delta spreads out around the mouths of the dry valleys of the Bride Hills (p. 357, Fig. 97), extending from Braust to Ballavair, but becomes attenuated and disappears southward. A fringe of similar or more sandy material, probably the edge of a delta which has been swept away by marine encroachment, occurs along the E. coast S. of Ballavair. Over the rest of the area these superficial gravels have either not been deposited in sufficient quantity to cover up the irregularity of the underlying surface of clayey drift, or have been carried off by later denudation. Hence we find a larger proportion of clay-land in Andreas than in the other northern parishes.

DREAS.

In the parts where clay lies near the surface there are several small tracts lying a little below the general level which appear to have been liable to occasional or seasonal floods until artificial drainage was instituted. In these shallow basins, the clay, though found at a foot or two beneath the surface, is usually covered thinly by dark silty sand or loam, rarely sufficiently thick to map as alluvium; as, for example, in the depression between Andreas and Lowdas. Where, however, a basin of this kind is continued into a definite strip of valley-alluvium, as in the instance south of Ballaseyr; or where it still contains bog, as in the hollow at Seaview; it has been shown on the map. These little basins generally give rise to small winding valleys, which like those of the Jurby platform have been excavated into the drifts down to the level of the Lhen or upper Curragh terrace, and now contain only a runnel of water in an artificial ditch. The four principal of these channels have been shown on the one-inch map by slightly exaggerating their strip of alluvial wash; of which two drain south-westward to the Lhen, and two southward to the eastern Curragh. An antler of an elk was found in draining one of these depressions, in a field 200 yards west of Ballalheaney, in a bed of peat covered with sandy wash at 4 feet from the surface.

The Curragh margin is not so well defined in this area as farther west, the drift-slopes as a rule disappearing gradually beneath the alluvium, with only faint indications of the beach-like lower platform; while spurs and islands of sand and gravel or clay, rising slightly above the Curragh, denote original inequalities of the glacial deposits which have not been completely buried by post-glacial accumulations.

Old marl-pits, often of large size, are very numerous in the tracts of clay; many of them now form ponds, but some in which sand has been reached beneath a clay-bed are dry and still partly show a section; they are usually sunk in a deep-red clay, generally containing only a few small pebbles, but now and again a large far-travelled boulder. These pits are not confined to the area mapped as boulder-clay, having often been opened where the clay has been covered with sand and gravel of mappable thickness, as around

Ardonan and Regaby. At a small brickyard at Regaby Beg the following section was exposed, all the beds being very irregular :—

	Feet.
Soil - - - - -	1
Sand and gravel, with shell fragments - - -	0 to 3
Red loamy clay with small round stones, and a thin band of pebbly clay with crumbs of shells ; in places mixed and contorted with patches of sand and gravel - - -	6 to 8
Sand (in bottom of pit) - - - - -	0 to 2

Another brickyard at West Craig, 700 yards W. of St. Jude's Church, had been worked in a similar but rather more stony clay. A small pit, 7 feet deep, in the corner of a field 200 yards N.W. of Ballabeg, on the east side of the high-road from St. Jude's to Andreas, revealed a confused admixture of pebbly boulder-loam with sand, silt and clayey gravel—in fact, such material as could not be defined either as boulder-clay or as sand and gravel, being just half-way between ; the pit is at the edge of a mound which rises above the general level of the platform and appears to be an outlier of the Bride Hills.

In the vicinity of Ramsey the drifts rise more sharply out of the alluvial flat, and the ground becomes undulating, apparently indicating original inequalities of accumulation unmodified by delta-gravels. The Sulby River has cut a steep bluff in its north bank between Riversdale and Ramsey, in which the following section is exhibited :—

NORTH
RAMSEY.

	Feet.
At the top : Sand and rounded gravel - - -	6
Red pebbly clay - - - - -	6 (or more)
Stratified sand, with red loamy bands - - -	30 "
Shell-fragments abundant on the talus.	

Mr. Kendall mentions that at Riversdale the sands met with in a well yielded several specimens of *Nassa serrata*, Broc. (*N. reticosa*, Sow.) (op. cit., p. 410).

The Curragh Basin.

The Curragh Basin, using the term in the broader sense to include the lower Late-glacial flood-platforms as well as the alluvial tracts, is sharply bounded on the west by the western horn of the drift hills, which rise to 150 feet above O.D. between Ballaugh and the coast. This high ground has been eroded into a steep sandy bank, which runs north and south for 1½ miles from Broughjaig near Ballaugh to Ballakinnag. In several places along the summit of this bank neolithic chipped flints are abundant. At its foot is spread out the broad delta of slaty gravel from Glen Dhoo (p. 448), which falls from a level of 130 feet just inside the Glen to 50 feet or under near Ballakinnag, where it is merged into the low platform of the northern margin of the depression. Through this delta the present stream from Glen Dhoo has carved a little valley, extending to the coast at Ballakinnag (p. 104), which contains narrow strips of alluvium of some antiquity. In the east bank of this stream, near Ballacorage, 200 yards S. of St. Mary's Old Church, a small section was exposed in 1894, showing 2 feet of grey marl resting on 6 inches of peat, with slaty gravel and sand below. Specimens of the marl and peat were washed and sifted by Mr. J. Bennie, and the material examined by Mr. C. Reid, but proved poor in results, the only determinable plant being *Isoetes*. Peat is reported to have been dug beneath 6 feet sand, on the platform near the farmstead of Corvalley 300 yards farther south, but is not now visible. The low land to the west of the stream, south of Ballacooiley (Sh. 4) is stiffish, as if the gravel were mixed with clay in this quarter.

BALLAUGH

The larger of the curious hollows in the gravel delta east of Ballaugh, in which the Irish elk-remains occur, have been described in a previous chapter (p. 375). Smaller hollows, of similar character except that they are dry and sandy in the bottom, occur around *Ballacrosna* (Sh. 4), and Squeen 200 to 300 yards east of those described; and the extremely irregular and deeply indented boundary between the boggy Curragh and the dry ground at the edge of the gravel platform immediately to the eastward, between *Ballavolley* and *Ballaterson Beg*, probably indicates that more of these depressions are hidden beneath the Curragh peat. It is not unlikely that in early Post-glacial times the flood-waters from Glen Dhoo have occasionally taken this course into the old lake. Northward along the platform the slaty debris dwindles in size, and the ground becomes more sandy as we reach the outer fringe of the delta; and north of Ballacorage, where shown by the dotted line engraved on the map, the slaty gravel loses its identity. Between this line and the Killane River the surface-geology is difficult to render. The tract appears to represent that portion of the bottom of the Late-glacial lake upon which very little sediment was deposited. Judging from the coast-section (p. 423) and from the sharp truncation of the Jurby platform, the upper part of the glacial deposits have been denuded off, down to the level of about 40 feet above O.D., and a thin irregular covering of sandy wash spread out over the denuded surface. On the map the tract has been shown by the same colour as the Late-glacial Flood-gravels, since no practicable alternative suggested itself; but this must only be taken as representing the age of the terrace, and not the character of the deposits upon it; the soil is generally a dampish sandy loam with few stones. There are large old clay-pits at Ballamona Mooar and Ballamona Beg which show from 2 to 5 feet of discoloured sandy wash with a little gravel and yellow sand, resting on thick warpy clay which is probably that of the middle portion of the drifts in the cliff-section; no stones were seen in this clay, but two or three far-travelled boulders lying on the floor of one of the pits had probably been dug from it. Several smaller pits, mostly without present exposures but apparently in similar deposits to the above, are scattered over the area farther east, between Ballamona and Close Taggart, and also along the northern margin of the Curragh north of Killane river, between Ballacain and Sandygate. I was at first of opinion that this warpy clay might represent the deposit in the stiller waters of the lake at the 40 foot level; but after re-examining the coast-sections between Jurby and Ballaugh, I concluded that it was of older date, and, though probably of fresh-water origin, was derived direct from the ice-sheet.

This sandy flat sinks gradually and irregularly eastward until covered with more modern alluvium, which at first occurs in detached patches occupying little basins, or in broken strips; but afterwards expands into the broad level sheet of the Curragh. The different divisions of the Curragh, with their respective levels, have been explained in the general chapter (pp. 406-9). The south-western basin extends up to the foot of the steep bluff of slate known as Gob y Volley, having apparently been screened by this headland from the mountain-detritus which has been swept down the valleys and usually occupies a platform between the hill-slopes and the alluvium. The middle of this basin is still a peat-bog, but along its ill-defined western boundary a thin irregular bed of blue silty mud overlies the peat.

BY.

The embayment in the hills at the mouth of Sulby Glen is occupied by a broad delta of slaty gravel, 60 to 70 feet above O. D., which runs up to the foot of a steep bank eroded into slaty till. East of Cronk Sumark this old flood-gravel forms a well marked terrace 10 to 20 feet above the present alluvium of the Sulby; and on the north side of the hill overlies yellow sand belonging to the Extra-insular drift, which is dug for building purposes. This delta, furrowed by an ancient flood-channel (p. 407), stretches out northward in long low spurs into the Curragh, with level tracts of blue alluvial mud lying between and partly overlapping them. There is a tradition in the neighbourhood that the Sulby River once escaped in this direction to the Lhen; but the story, like that regarding the growth of The Ayre beach (p. 402), has probably been suggested by the shape of the

ground rather than by ancestral recollections as claimed, as this condition is not likely to have obtained during historic times. The above-mentioned spurs occur at intervals from The Rule on the west to Closechyrrim on the east, dying down gradually to the Curragh-level northward. The main road leading across the Curragh from Sulby Glen Station to Sandygate takes advantage of one of these gravelly rises, while another, $\frac{1}{2}$ mile farther east, is traversed by the road from Sulby Bridge Station to St. Jude's. The alluvium on the northern margin of this part of the depression is more or less sandy from the washing in of the drifts. It contains in many places beds of peat with large trees, generally covered with sandy wash or blue marly clay; but the only sections are in the banks of shallow drains, so that the full thickness and sequence of the post-glacial deposits cannot be ascertained. The bog-wood is best exposed in the drain to the east of the Sandygate road, S.E. of where the road level '36' is marked on the one-inch map; it may also be seen in the same drain west of the road, $\frac{1}{2}$ mile farther south.

There are traces of sandy terraces at the northern margin of the Curragh between Closeakewin and Cronkglass, and again S. and S.E. of Ardonan, probably representing the 40 ft. terrace of the country farther west; but they are too indefinite to be mapped separately, and have therefore not been distinguished from the glacial sand and gravel. The islands of dry sandy ground in the Curragh E. and N.E. of Closechyrrim, referred to in the previous chapter (p. 409), probably constituted the islands of Lake Mirescogh mentioned in the old "*Chronicon Manniæ*."¹ The best defined LEZAYRE. of these is that on which the farm of Close-an-Allan stands; it is about 100 yards long by 100 to 200 yards broad, and is composed of yellow sand and drift-gravel, apparently resting in places on red clay, and overlain around the margin by a wash of peaty sand. Another tract of similar composition, but lower and less definite, lies $\frac{1}{2}$ mile to the southward, around Ballamona; while the third forms a low narrow strip on the north side of the Sulby River west of Lezayre Station. The last two seem to be portions of a sandy bank which may once have run continuously under the slate bluffs between Sulby Glen and Glen Auldyn, but has now been cut up by the Sulby River and partially overspread by slaty debris from the little ravines at *Glenduff*, *Glenramman*, and *Glionne Killey* (Sh. 5). The river-alluvium is bounded by a sharp bluff of this drift between Sulby Bridge and Ellanbane, in which yellow sand is frequently revealed; and the same is again the case at Ballakillingan; the sand is obscurely associated with slaty drift where it approaches the solid rock, probably in the same manner as in the coast-sections at Ramsey and Gob ny Creggan Glassey (Figs. 91, 92 and 93); thus, 10 ft. of slaty till is visible in a little gully near Kerroo Moor, 150 yards west of *Bellevue*, (Sh. 4).

The character of the alluvium in the Lezayre Curragh has been modified by the presence of this sandy border on all sides, its soil being for the most part a lightish loam. In peaty earth thrown out from a trench 550 yards N. of Ellanbane were many hazel nuts, some gnawed by a rodent, together with a horse-chestnut and cherry-stones. The little valleys which drain from the drift-platform into the embayment of alluvium north of Riversdale have already been noticed (p. 436); they must have brought down much material into the hollow, and can scarcely have transported it thence through the old lake into the sea, so that this part of the basin may originally have been of considerable depth.

The conditions at the mouth of Glen Auldyn are precisely similar to those at the mouth of Sulby Glen. A broad flat delta of slaty gravel and wash, furrowed by old channels, is spread out around its entrance, and sends processes (shorter than those of the Sulby) into the alluvial flat. When traced up into the valley, the delta contracts into a terrace lying at the foot of an eroded bluff of slaty till. This terrace at first ends off

MILNTOW.

¹ See Cumming, "*Isle of Man*," p. 217, where an account is given of "a notable miracle wrought [in 1249] by the intercession of St. Mary of Rushen" in the escape of a prisoner from one of the islands, as recorded by the old monks.

against the alluvial flat of the stream in a steep bank, which gradually loses its distinctness as the bottom of the valley rises, and finally disappears. To the east of the delta a bank of the Extra-insular drift is again found at the foot of the slate-bluff, between *Crossaigs* and *Claghbane* (Sh. 5), and extends thence up to the coast. It consists at first of yellow sand with streaks of red clay, but N.E. of Claghbane stony red clay of the usual Extra-insular type occupies the surface. At the foot of the bluff this drift is overlain by slaty rubble, as in the adjacent cliff-section (Fig. 91).

The alluvium bordering the Sulby River between its confluence with the Glen Auldryn stream and Ramsey is so little above present high-water mark that the tract can scarcely have escaped estuarine conditions during the Raised Beach period; but so far as the insufficient exposures in the ditches show, the material maintains its fluviatile character close up to the town. The Harbour and its vicinity have already been described (p. 430).

CENTRAL DIVISION.

(Sheets 6, 7, 8, 10, 11 and 14, and parts of 4, 5, 9 and 13 of 6-inch map.)

Western Coast between Gob ny Creggan Glassey and Peel.—South of the point where the slate makes its appearance in the cliff (p. 121) the drifts are banked irregularly against the flanks of the massif, lying thicker or thinner according to the slope of the surface upon which they rest, in some places dwindling to a mere film, and in others, where they fill bays in the ancient coast line, forming the greater part of the cliff-section. In composition the deposits show the same irregular intercalation of Insular with Extra-insular drift as already described at Glen Moobar and Gob ny Creggan Glassey, the one material or the other predominating according to the local conditions.

For half a mile to the southward of the *Glion Shellan* exposure (Fig. 93, p. 348) the cliffs here and there present nearly similar sections; but at Lady Port the slaty till and rubble increase, in the old valley of *Glion Cam*, at the expense of the red drifts, and almost monopolize the section.

At Gob ny Deigan the foreign drift regains prominence, consisting, at the base, of 15 feet of partly indurated shelly gravel; which passes up into slaty till; overlain by red clay containing shells, and sand. South of this point, at *Lhiannag* (Sh. 6), the drift increases greatly in thickness, having obtained lodgment in the broad hollow around Ballabooye, through which the ravine of *Glion Broigh* has been excavated since glacial times. Down this hollow a great amount of partly re-arranged grey slaty drift has been swept from the hills; this material overlies contorted red clay and sand, both in the cliff-sections and in the steep sides of the glen. The railway-cutting at the top of the slipping cliff above *Lhiannag* also shows good exposures of drift, the general succession being the same as at *Glion Shellan*. At the southern end of *Lhiannag* the cliff reveals the following section:—

	Feet.
At the top:—Slaty gravel interbedded with and passing into Red clay, sand and gravel with shell fragments	} about 70
on Blue slaty till and gravel	
on Slate.	about 20

A section 400 yards inland, in the S. bank of *Glion Broigh* 40 yards E. of the highroad, shows:—

	Feet.
At the top:—Grey and blue slaty clay, partly stratified	6
Blue slaty gravelly till, partly stratified	10
Contorted red clay and sand, with a few shells	30+

The surface of slate beneath the drift in the little headland north of the glen exhibits faint indications of striation running W. 10° S.—E. 10° N. South of Ballabooye the slate hills begin to fall back from the coast line, and the shelf below them is then invaded by the red drift, which forms a mounded surface of sand, gravel and red clay; while in the cliff-section these deposits are seen to overlies dark slaty till in which there are a few foreign boulders. At Wills Strand the Peel Sandstones set in, the slate hills gradually receding farther from the coast, and the red drift still following them inland and usurping the surface at the expense of the slaty drift. These phenomena mark the commencement of the pressing in of the lower layers of the ice-sheet upon the Peel embayment which has been described in a previous chapter (p. 351).

BALLAN-
AYRE
STRAND.

Opposite White Strand the grassy sloping cliff over 100 feet high, is wholly composed of drift, but probably in part slipped, though the base of the glacial deposits at one point apparently descends slightly below high-water mark as if occupying an obliterated valley. Many large erratic blocks lie on the shore here between tide-marks, including one of grey Galloway granite measuring 8 feet by 5 ft. by 4 ft.; another, apparently Shap granite, 4 ft. by 3 ft. by 1 foot; others are of pebbly grit, Ailsa Craig, etc. At *Cain's Strand* (Sheet 9), where sandstone forms the lower part of the cliff, the drift-section is clearer, showing: at the top, sand and indurated gravel; resting on sand and coarse gravel with irregular curved kame-like bedding; and brown slaty till containing shell fragments, at the base. Two little glens open out upon the shore at this place within 100 yards of each other; the more northerly is excavated nearly down to sea-level entirely in drift, the following being the section 200 yards from the coast:—

WHITE
STRAND.

	Feet.
At the top:—Rolled gravel and sand	20
Slaty till with a few shell-crums and some foreign stones	10
Sand and gravel, with many shell fragments	20
Clay? concealed by talus.	

In the neighbouring glen the red sandstone lies at a comparatively high level, and the ravine has therefore not been excavated nearly so deeply; another instance is thus afforded of sharp irregularity of the Pre-glacial surface masked by the glacial deposits. Among the boulders in the more southerly of these glens is one of coarse granite of unrecognised origin, measuring 5 ft. by 4 ft. by 3 ft., lying in the valley-bottom 150 yards from the cliff.

Where the coast takes a more westerly trend, S. of *Cass Stroom* (Sh. 9), the drifts thin away rapidly, until only a few feet of sand or red clay is found above the sandstone. At *Lhoob y Reeast* this thickens to 15 or 20 feet, but dwindles to a mere sprinkle between this place and *Creg Malin* where the sandstone cliffs end. We then reach the Pre-glacial depression of Peel Bay, into which the Extra-insular drifts are banked to a great thickness, both above and below sea-level. The Raised Beach is represented in this bay by a narrow terrace extending from *Creg Malin* to the Harbour, behind which rises the steep slope of the old cliff, to a height of over 100 feet at the eastern side of the bay but sinking gradually westward. This old cliff is composed entirely of drift, perhaps at the eastern end banked against a concealed Preglacial cliff or valley-bluff of sandstone. The greater part of its slope and the Raised Beach at its foot are covered by the town of Peel, and there is no natural section; but artificial openings in various places reveal sand, gravel and red stony boulder-clay, all of the Extra-insular type.

PEEL.

The foundations for the sea-wall built in front of the Raised Beach were excavated in sand and shingle. Clear proof that the red drifts underlie the bay was obtained from the works in connection with the extension of the breakwater which runs out from St. Patrick's Isle. The foundations of this extension were in purple boulder-clay containing a few shell-fragments. In 1893 I was able to examine the material from some borings into the sea-

bottom below low-water mark, made with a view to further additions to the breakwater, which gave the following results :—

Borings beneath the Sea in Peel Bay.

(The first column gives the engineer's journal ; the second, my notes on the material preserved.)

No. 1 BORING.

250 feet from end of old breakwater, or 50 feet from end of extension, on the S. side.

	Feet.	
Shingle - - -	- 6	} Recent.
Sand - - -	- 2	
Clay - - -	- 4½	
	12½	Purple boulder-clay.

No. 2 BORING.

Same distance from old breakwater as No. 1, but on the N. side.

	Feet.	
Sand - - -	- 3	} Recent.
Shingle - - -	- 3	
Mixture of sand and clay	½	
Sand - - -	- 1	Darkish sand.
Sand and clay - - -	- 1	
Clay - - -	- 2	Purple boulder-clay.
Sand - - -	- 2	Clean sharp sand (like recent sand).
	12½	

No. 3 BORING.

350 feet from end of old breakwater on the S. side.

	Feet.	
Sand - - -	- 2	} Recent.
Shingle - - -	- 2	
Clay and sand - - -	- 3	} Sandy purple boulder-clay.
Fine shingle - - -	- 2½	
Sand - - -	- 2½	
	12	Sharp sand and small stones (like recent beach).

No. 4 BORING.

Same position as No. 3 (on N. side ?).

	Feet.	
Sand - - -	- 2	Recent.
Sand and clay - - -	- 8	Purple clay mixed with sand.
Sand - - -	- 2½	Sharp sand.
	12½	

No. 5 BORING.

400 feet from end of old breakwater, on the S. side.

	Feet.	
Sand - - -	4	Recent
Sand and clay - -	6	Purple clay mixed with sand.
Sand - - -	2	Dark clayey sand.
	12	

On St. Patrick's Isle only a trace of drift is found outside the castle walls, **PEEL** but inside there is a little patch of gravelly and red clayey material **CASTLE** which has been much disturbed for making earthworks (see Fig. 39, p. 147). An ancient well at the edge of this patch is commonly reputed to yield an inexhaustible supply of excellent water, but I found on close inquiry that as might be expected, its capacity is very modest; and as the place is frequented by crowds of visitors in the summer, the quality of the supply may also reasonably be doubted. It is worth noting in regard to the antiquities of the Castle that all the smaller and several of the larger of the stone cannon-shot which are preserved in the little Museum and are described as having been fired into the enclosure by invading Scots, are made of *Fordale granite*, carefully dressed into shape. Of the remainder, one or two are of a granite like the Galloway granite boulders; but there are several stones, more rudely shaped, of a pale softish rock, which do not seem to be of Insular origin. There are traces of a glaciated surface on the slate-rocks just outside the castle wall east of the **Prison** (see List, p. 477).

The description of the coast-section south of Peel is resumed on p. 460.

Eastern Coast between Ramsey and Douglas.

East of the section shown in Fig. 91, p. 346, the slate slope is too steep for much drift to lodge; and as the upper part of the cliff is grassy, there are few exposures in the little that does occur, which appears to consist of slaty rubble with interbedded streaks of red clay. The slipping of masses of this material down the dip-slopes of slate produces striations on the rock-face at the summit of the cliff, which resemble those due to glacial agency and have been assigned to that cause (p. 359, footnote). Although a Pre-glacial cliff no doubt existed in this locality such striations may be found on rock-faces which cannot have been in existence in Glacial times. They occur here and there all along the east coast wherever the conditions are favourable for their production. That they should resemble glacial markings is to be expected, since both are alike due to the sliding of stony rubble under pressure in a definite direction over the rock-surfaces, the difference being that in the one case the slope is essential and always determines the direction of the striæ, while in the other it is non-essential and the striæ only accidentally coincide with it.

The presence of red boulder-clay on the foreshore outside the narrow rock-shelf between Ballure and Lewaigue has previously been mentioned **PORT LEWAIGUE** (p. 347). In Port Lewaigue (Sh. 5) this rises along the cliff into a pre-glacial hollow and is exposed in the disused brickyard on Tableland Point (Gob ny Rona of revised Ordnance map) in a section exhibiting up to 15 feet of red stony clay with streaks of stoneless clay and of sand and gravel. Mr. Kendall, who figures this section (in Fig. 9 of his plate), notes the occurrence of a few shell-fragments in the lower part, and states the order of prevalence of the stones to be as follows:—"Red Sandstone, Granite (all Scottish), Silurian Grit (probably from Wigtonshire), Clay Slate, Vein Quartz, Flint." (Op. cit. p. 415.) Similar material lines the cliff-top up to Port e Myllin (*Arwyllin* of 6 inch map), and probably also again underlies the lower part of the foreshore there. Having once obtained entry at this

low point, the red clay runs south-eastward up the depression between Maughold Head and Slieau Lewaigue (p. 347), occupying the whole breadth of the valley, but fading off into slaty drift on the western slopes, along the dotted line drawn on the map. On the eastern slope it is covered by or passes into a moundy sloping bench of gravelly drift, consisting of slate-fragments with a fair sprinkling of foreign pebbles. In the valley-bottom (in which are a few old clay-pits) the present drainage, artificially assisted, goes in part north-west to Port e Myllin, and in part south-east to Port Mooar; and in two places level patches of peaty alluvial wash indicate old flood-basins. The incurving coast-line south of Maughold Head intercepts the valley again at Port Mooar; and in the cliffs around this place and in patches on the foreshore the red stony clay, with interbedded sand and stratified stoneless clay, is here and there well exposed.

On the outer or northern side of the headland the slope is too steep to retain more than a little rearranged slaty rubble mixed with foreign stones. Glacial striæ occur at two or three places on the crest of the ridge, and afford remarkable proof of the swerving of the ice-flow in rounding this corner of the Island (see List, p. 476). Numerous large erratics are scattered upon the headland and its shores, regarding which Mr. Kendall notices the remarkable abundance of slaty quartzose grit, which he identifies with the Queensberry Grit of Wigtonshire (op. cit. p. 415). These boulders have been studied and catalogued by Rev. S. N. Harrison of Ramsey, who discovered, among other rare and interesting rocks, a rounded block of Arran Pitchstone (identified by Professor Zirkel), 4 feet in diameter, on the shore at Port e Myllin, and one of gneiss at Ballure.¹ A broken boulder in the east corner of a field 400 yards E.N.E. of Ballaterson East appears to be of Borrowdale lava, and Mr. Kendall records another Lake District rock, viz., Buttermere Granophyre, at Ballure.² As usual, however, the majority of the erratics are of Galloway granite.

A narrow strip of Raised Beach lines both sides of Port Mooar; and a broad rock-platform, slightly above high-water mark, indicates the old shore where the beach stuff is absent. As we pass southward from this inlet the solid rock rises in the cliff, and the red clayey drift becomes thinner and in places disappears. On the south side of Gob ny Garvain, where a little gravelly and red clayey drift rests in a slight hollow in the rock, the surface of the flags shows glacial striæ in two directions, the older, N. 10° W.—S. 10° E., and the newer, E. 10° N.—W. 10° S.; this is the more noteworthy as striated surfaces are of rare occurrence directly beneath the red drift. From this point to Port Cornah (Sh. 8) the drift, where present at all, is confined to mere traces of red clay mixed with local rubble and foreign pebbles, too impersistent to map. At the last-mentioned place a valley-terrace of gravelly drift, probably deposited by late-glacial floods, reaches the coast on the western side of the deep glen: and half a mile inland there are some fine sections in boulder clay in the glen (p. 450). For the next 1½ mile southward there is no drift in the vicinity of the coast. We then reach Bulgham Bay, where the profile of the cliff is unusual, an undercliff of slate, 30 to 50 feet high, forming the sea margin, with a great precipice rising to over 600 feet behind it, the two being separated by a gently sloping cirque-like platform which tapers out crescent-wise northward and southward. On this interspace some clayey slaty rubble containing a few blocks of Dhoon granite and a sprinkling of foreign pebbles has lodged; this resembles drift, and if really in place and not simply material dislodged from the cliffs, it would indicate that the inner cliff is pre-glacial. The platform is not easy of access, and is so cumbered with fallen blocks and overgrown with tall bracken in the summer that its exploration is difficult; the remains of a carefully constructed ancient pathway may be traced in the upper precipice. South of Bulgham, the inaccessible cliffs are composed

¹ "Boulders around the Maughold Coast," *Yn Lioar Manninagh*, vol. i, pt. 8, p. 208; see also Mr. Harrison's "Report of the Geological Section," *ibid.*, vol. i., pt. 11, p. 375; and Reports of Erratic Blocks Committee, British Assoc. Repts. for 1891, p. 297—9; 1892, p. 286—9; 1893, p. 521.

² Op cit., p. 415.

wholly of slate, until we round Laxey Head, where the coastline is broken by the preglacial valley of the Laxey River, which is lined on both sides by banks of drift (p. 451). A triangular strip of Raised Beach is preserved at the mouth of this glen. From the abrupt cessation of the solid rocks on the foreshore, it is probable that the preglacial valley is excavated below sea-level, and that its drift-filled channel underlies the beach, but no exposure was visible on the shore during my examination of the area. This matter may be of practical consequence if new harbour-works be constructed at Laxey. It is also not unlikely that drift may exist beneath the beach exposed outside the rocky shelf at low spring tides for some distance south of Laxey, the conditions bearing much resemblance to those between Ramsey and Lewaigue.

LAXEY I

Between Laxey and Garwick the slate cliffs frequently have a capping of rubbly drift, but being dip-slopes, rarely show sections at the top. The cuttings of the electric tram-line to Douglas, which hugs the coast, have however made good this deficiency. At Ballybeg the cutting which crosses an old burial ground with stone cists reveals 6 feet of slaty gravel-drift, becoming rather clayey in places towards the top. South of this locality the excavations show a more clayey material of variable thickness, containing a few blocks of Dhoon Granite.

In Garwick the drift is again deeply banked in a preglacial hollow, which has been partly re-excavated to form *Glen Gawn* (Sh. 11). There is a good section at the mouth of this glen in a cut-road descending the cliff on the northern side, showing 20 feet of grey till in which the majority of the stones are slate, but with a few foreigners. In the stream-bed a curious unidentified boulder of richly micaceous garnetiferous pegmatite was found by one of the cottagers at Ballig, from whom we obtained specimens. Between *Gob ny Stowell* and *Braggan Point*, $\frac{1}{2}$ of a mile south-east of the glen, an irregular strip of red pebbly clay 200 or 300 yards in length, containing a few foreign pebbles, is lodged in an unusual position upon the steep slope just above the actual cliff. This has furnished the Laxey miners with material in which to stick their candles, and appears to have given rise to the name of the headland, which is not very appropriate considering the small extent of the patch and the bold rocky character of the whole promontory. Glacial striæ at three places on the headland in the vicinity of the cliff, along with other examples farther north and farther south, indicate a general ice-movement parallel to the coast (see List of Striæ, p. 477).

CLAY HI

On the southern side of Clay Head there is little or no drift until we reach the depression at Port Groudle (Sh. 14), where on the north side of the inlet a little platform of rubbly local drift, containing a few red sandstones and other foreign pebbles, with a depth varying from 8 to 20 feet, is exposed in the cliff section.

On Banks Howe (Sh. 14), as is so often the case throughout the Island, the steep northern side of the hill is practically free from drift, and is scored in many places by glacial striæ, sometimes in more than one direction (see List), while the less steep southern side possesses an irregular capping of till and glacial rubble, as may be seen in the cliffs to the east of Onchan Harbour. Fragments of the Groudle mica-diorite (p. 152) occur in this drift. Similar drift is exposed in the tram-line cuttings between Onchan Harbour and *Port Jack*, and at the cliff-top west of *Port Jack*. All along the east coast the foreshore is sprinkled here and there with extra-insular boulders; a notable example occurs on the western side of *Port Jack*, where one of the blocks is a rounded mass of grey (Galloway?) granite 6 feet in diameter. At the same place are smaller blocks of Dhoon Granite.

BANKS
HOWE.

As we enter Douglas Bay (Sh. 13) the drifts thicken, but are for the most part concealed by buildings. At *Derby Castle* a strip of Raised Beach is preserved at the foot of the slate cliff, and continues thence around the bold crescent of the Bay up to the Harbour. It is protected throughout by a sea-wall, and in the middle of the bay has a little blown sand upon it. This low terrace with its open front, backed by large houses and the steep bluffs of the old cliff behind, combine to give that imposing aspect which

DOUGLAS
BAY.

GLAS

characterizes Douglas as viewed from the sea. At Strathallan Park the top of the cliff shows a gravelly rubble of slate with a few foreign pebbles, becoming more clayey towards the surface. This is broken by *Glen Crutchery*, but is continued again on the south side, and near *Athol House* begins to show streaks of red clay. At *Falcon Cliff*, as the drifts thicken the presence of the Extra-insular material becomes more marked, beds of stratified sand, gravel and warp associated with tenacious red clay making their appearance. South of the last-mentioned place the preglacial cliff of slate recedes inland, and the glacial deposits which are banked against it occupy the whole of the high bluff south of the ravine behind *Castle Mona Hotel*. At the mouth of this ravine there are sand pits showing 10 to 12 feet of fine stratified sand, with bands of loam and lenticles of gravel; and near the base, a bed of stiff red and purple clay with a few stones; below which is clayey gravel; the whole mass resting against, and perhaps partly slipped upon, a steep rock-slope. This section, like those in similar positions in localities previously described (Figs. 91, 92, and 93), represents the wedging out of the Extra-insular drift against the higher ground occupied by the slaty drift. There seems to have been a pre-glacial valley in this vicinity, perhaps a former outlet of the River Glass, into which the lower layers of the ice-sheet have entered. A gap a little over 100 yards wide in the rock-reefs at low water on the shore nearly opposite, which is indicated in the ornamentation of the ordnance map, probably represents the prolongation of this channel below sea-level. Some patches of indurated slaty gravel resting on a surface of decomposed slate were exposed in 1896 on the beach to the westward of this gap; but recent beach-stuff hid the part of the shore which is most likely to be underlain by drift alone.

South of the section above described the slope of the old cliff becomes less steep and more encumbered with buildings, and there are no more open exposures. The character of the drifts in the upper part of the town was, however, revealed in drainage and other works carried on during our survey; and the evidence thus obtained supplements that of the cliffs.

There is a small section in brown weathered rather gravelly boulder-clay in a cutting on the Peel Road at the south-western outskirts of the town, half a mile from the shore; and similar material appears to occupy the surface over the whole of the rounded hill between the valley of the Glass south of Cronkbourne (p. 456), and Douglas Bay. The majority of the stones in this clay are of slate, but with a fair sprinkling of foreigners. Boulder-clay of this kind was exposed in Bucks Road and its prolongation up to Woodside Terrace, and also in Upper Derby Road, and in several places farther west. In the slight depression farther north, which perhaps marks the filled-in preglacial valley previously mentioned, the drift becomes more sandy, and on both sides of Ballaquale Road sand is the prevalent constituent and has been dug in several places. It appears to be continuous with that seen in the cliff near Castle Mona. It was well exposed in the tramway excavations and in the foundations for the tramway engine-house. In a sand-pit opposite Ballaquale Cottage the section showed 3 to 5 ft. of stony loam (perhaps partly wash), on 12 feet or more of sand with contorted warpy streaks; gravel was said to occur below the sand. On the rising ground north of the sandy hollow the drift gradually resumes its previous stony-clay character.

In the lower part of the town bordering the harbour the Raised Beach fades off indefinitely in the alluvial river-flat. At the brewery on the north side of the harbour, 40 yards east of the Douglas Bridge road, I was informed that a pipe-well starting at about 17 feet above O.D. passed through 14 feet of made ground and loose shingle, and 26 feet of compact clay, to slaty rubble yielding fresh water of good quality. Another well, 9 yards north of the last, reached the water-bearing stratum at 30 feet, the compact clay being only 16 feet thick. Nuts are said to have come up the pipe from the bottom of the well; but as the "compact clay" is likely to be boulder-clay and not alluvium, the evidence seems scarcely sufficient to establish the presence of vegetable remains at this depth.

Interior of the Central Division.

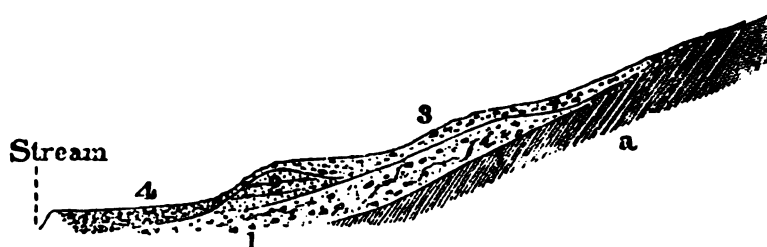
At the north-west corner of this area, between Ballaugh and Kirk Michael (Sheets 4 and 7) we find the sandy drift-mounds sweeping up to the foot of the solid hills, and south of Bishops court mounting a little way on their slopes. The basins among these mounds bordering the massif appear to have held temporary lakelets, of similar character to the Curragh Lake, but of much smaller dimensions. The largest of these minor basins lies between Orrisdale and Bishops court; it has been distinguished on the map by the 'Late-glacial Flood-gravel' colour and sign, but its level floor is for the most part composed of sandy or silty wash, with a little patch of newer peaty alluvium at the southern end. It probably persisted as a lake in flood-times until drained by the excavation of *Glen Trunk* (p. 425). A small pond still existing on the north side of the highroad half a mile N.E. of Bishops court appears to occupy a natural depression. South of Bishops court the railway passes through the mounds in a deep cutting, which is, however, now obscured; it has consisted mainly if not wholly of sand and gravel containing shell-fragments. To the east of this place the slate hills have a more gradual descent than usual; and here, east of Whitehouse, the gravel mounds, composed chiefly of slaty detritus, are found up to an elevation of 400 to 500 feet, resting in part on the solid rock and in part on clayey rubble-drift. They extend southward in a broken chain at about the same level up to Glen Wyllin. Cronk Urleigh, on the east side of this glen, is one of the most prominent of these mounds, while on the opposite side they line the crest of the valley and rise up on both margins of the dry rock-gully near Ballalheigh, as shown in the ground plan Fig. 102, p. 365. The railway intersects these mounds again near East Berks, in a cutting showing 30 to 50 feet of sand and gravel, possibly resting on slaty till almost concealed by talus. They also extend inland along the upper slopes of Glen Mooar for more than a mile, entering well within the slate hills; as may be seen on both sides of the valley around Chester, where small pits and road-cuttings reveal sand and fine slaty gravel containing many foreign pebbles (porphyry, flint, etc.), with some streaks of warp and red clay. In the lower part of Glen Mooar, just below the waterfall known as *Spooyt Vane* (Sh. 7), and extending thence for 250 yards on the east bank of the stream, there is a grand cliff of slaty till, 40 to 60 feet high, containing, like that at the mouth of the Glen (p. 428), a few foreign pebbles and shell-crums. Similar walls of local till are found in Glen Wyllin west of Cronk Urleigh, where the stream has cut a deep inner ravine in the glacial infilling of its old valley, the remnants of high-level fluvial terraces here and there recording the progress of its re-excavation. Three large boulders of Galloway granite and one of coarse grit were noticed in this ravine. As previously mentioned, the 'Fullers Earth' which has been dug in this glen at a place to the southward of Erinville, marked *Summer Ho.* on the six-inch map (Sh. 7), forms part of this drift. In the upper part of the glen, near Cammall, the till is overlain by a gently sloping sheet of slaty gravel, which was probably formed at the same time as the great terrace of similar material at the mouth of the glen around Kirk Michael (p. 374), and dates back to the closing stages of the ice-invasion. There are good exposures of drift of strictly local derivation at several places in *Glen Kiark*, between Sartfell and Slieau Freoaghane, up to its head at over 1,000 feet above sea-level; and again in the north branch of the other feeder of Glen Wyllin, east of Ballalionney. The mountain-ridge itself is peculiarly free from drift right up to its northern extremity in Slieau Curn; nor, so far as could be discovered, does it possess any straited surfaces. This condition is probably due to the floods which have swept across the corner of the Island during the melting of the ice-sheet, as shown by the dry gullies on the lower slopes described in a previous chapter (p. 364, Figs. 101, 102), and by similar indications which may be traced up to the very summit of the ridge. Thus, 200 yards N. of the boundary fence between Slieau Curn and Slieau Freoaghane, a channel (briefly referred to on p. 363) has been excavated in the slate, with a floor 10 to 20 yards wide and walls 20 to 40 feet high, starting on the crest at an elevation of 1,058 feet and descending the slope for a short distance in a south-westerly direction.

BISHOPS-
COURT.KIRK
MICHAEL
DISTRICT.

GLEN DHOO, Where Glen Dhoo opens out upon the gravel platform at Ballaugh it contains on both sides well-marked terraces continuous with the platform; and these rise with the valley from an altitude of 120 feet above O.D. at the mouth to about 200 feet at Ravensdale, a mile farther south. Above this place the valley-bottom contracts and the terraces can scarcely be separately distinguished.

The occurrence of foreign drift in this glen has already been discussed (p. 352); it consists mainly of yellow sand, with some gravel and red clay containing foreign pebbles. Found on both sides of the valley above the gravel-flat, it is best developed on the eastern side, where it extends up to the mouth of Ravensdale. Its relation to the local drift is shown in the following diagram (Fig. 106).

FIG. 106. *Diagram of the Drifts on the eastern side of Glen Dhoo, north of Ravensdale. Length of section about 600 yards.*



- 4 Late-glacial Flood-gravel.
- 3 Slaty rubble, with some striated fragments: = rearranged drift.
- 2 Yellow sand streaked with gravel with foreign pebbles, and with red clay; mixed towards the top with No. 3.
- 1 Slaty till.
- a Manx Slates.

The slaty rubble (3) of this section is a form of the local drift which is plentiful among the hills both on the gentler slopes and on level ground. It appears to represent the material left loose on the surface at the melting of the ice sheet, and has no doubt since been in part redistributed by subaerial agencies. When swept into the valleys, it probably furnished the principal portion of their terraces and deltas. It is generally, as in the present instance, sharply distinct from the till when this is present, but often merges into the stratified drifts.

Towards the head of Glen Dhoo, the drift is limited to a narrow strip entirely of local origin; and the same is the case in its tributary, Ravensdale (*Glen Shoggle* of 6-inch map, Sh. 7), at the head of which there are good exposures near Nascoin. In a high-lyingcombe near the head of the main glen, on the northern side of Slieau Dhoo, there is a small crescentic mound, apparently of coarse local rubble, which has been shown on the map by 'boulder-clay' colour. It has somewhat the aspect of a valley-moraine, but the hollow seems too small ever to have held a moving glacier. On the rock-surface below the entrance to this comb: some doubtfully-glacial striæ were observed, the only examples found in this part of the island (see List, p. 476).

The high moorland ridge between Glen Dhoo and Sulby Glen is for the most part free from mappable drift, though loose rubble with a peaty covering lies rather thickly upon it S.W. of Killabraggah (Sh. 7). The short deep glen, tributary to the Sulby, to the west of Mount Karrin, has a thickish bank of local till in the bottom, which is well exposed on the east of the stream, opposite Earybedn (Sh. 4).

In passing up Sulby Glen from the mouth (p. 438), we find a narrow strip of local drift on the east bank, forming a definite feature, but not often seen in section. The river-alluvium is broader than usual, and probably somewhat ancient; and the stream has not reached its pre-glacial floor until we are two miles up from the entrance of the glen. Above this point there is very little drift in the valley, or in that of its tributaries, until we reach the head-waters. On the west bank opposite Druidale farmstead we have an excellent example of those effects of temporary post-glacial stream-deviation described on p. 372, in the form of a deep rock-gully which gashes the valley-wall high above the present river. Other deviations are indicated $\frac{1}{2}$ mile higher up the valley, where the river does not seem yet to have found its buried pre-glacial bed. In this locality high banks and cliffs of slaty till, rising in places up to 70 feet in height, form the southern side of the valley and continue up to the head-waters, at over 1,000 feet above sea-level. In two places in these excellent sections I noticed dragged-out streaks of red clay and sand of Extra-insular aspect among the local till, but failed to find any foreign pebbles.

SULBY
GLEN.

A narrow tongue of this drift sweeps across the col, at 1,100 feet, between Sartfell and *Slieau Maggle* (Sh. 7), into the basin of the Neb River (p. 453), while the main mass spreads out in an irregular sheet eastward up to the slopes of Beinn-y-Phott and Snaefell; it is well exposed in places in the upper part of *Glen Crammag*; and less clearly in the glen west of Snaefell, where it runs up to 1,350 feet and crosses the col to the head-waters of the Laxey River (p. 451). It is frequently covered by boggy hill-peat, which attains a depth of 6 feet or more on the northern slopes of Beinn-y-Phott, and here has been extensively dug. At the higher elevations the clayey till becomes more rubbly, and on the steeper slopes fades off into moundy slaty debris containing many scratched stones.

Similar material sweeps round the northern shoulder of Snaefell, and again crosses into the Laxey basin at an elevation of 1,380 feet; while northward and north-eastward it extends to the head of Glen Auldyn and of the eastern tributaries of the Sulby, where however it is thinner, less continuous and without conspicuous sections. The northern side of *Slieau Monagh*, on which occurs the glaciated quartz-vein of Creg Bedn previously described (p. 361 and Figs. 99, 100), is almost free from drift; as is also the greater part of the high moorlands between Sulby Glen and Glen Auldyn. The northern end of the ridge, above Ballamanaugh, differs from the rest of the northern bluffs in being apparently swarthed in drift to more than half its height, perhaps due to its sheltered position within the mouth of Sulby Glen. In the Narradale depression the drift is thinly spread, except in one portion of the lower part of the glen, half a mile E. of Cronk Sumark (Sh. 4), where the stream appears to have broken into an old ravine filled with till.

In Glen Auldyn the phenomena of Sulby Glen are repeated, the local drift occurring as a narrow sloping platform chiefly on the eastern side of the stream, with good sections, showing 20 to 40 feet of slaty till, near the head-waters. Its smaller tributaries descend over steep slopes of bare slate, but intersect this platform in the trunk-valley, while their gathering ground on the upland is generally more or less drift-covered. On the high moorland to the eastward which culminates in the long steep ridge of North Barrule and Clagh Ouyre (p. 139), rubbly drift, based in places on slaty till, forms a fairly continuous sheet covering the smooth slopes below the broken craggy crest, as may be seen in the cuttings of the mountain-road; but this sheet splits northward into lobes at the head of the little glens which gash the plateau above Ramsey, leaving the intervening ground for the most part free from drift. On the ridge itself, and scattered blocks of local dyke-rocks and quartz, with occasional glaciated fragments of slate in the thin surface-rubble, would suffice to prove that ice had swept over the crest, were other evidence wanting. But still more convincing proof is afforded by the glacial striæ which are found at intervals along its whole length, from *Slieau Lcwaigue* close upon the east coast; across North Barrule and Clagh Ouyre to Snaefell; and thence across Mullagh Ouyr, Carn Gerjoil, *Slieau Ree* and the more westerly

GLEN
AULDYN.NORTH
BARRULE
AND
SNAEFELL
HILL-CHAM

spurs, up to the central valley. As the position and character of these striae are indicated in the List (p. 476), they require no further description. In many other places where no striae could be detected, the rock-surface is distinctly *moutonnée*.

There is a little rubbly and clayey local drift around the northern end of North Barrule near Dreem e Lhergy, and this spreads in a thin covering southward and eastward around the flanks of Slieau Lewaigue, descending into the Cornah valley in the one direction, and in the other to the western side of the Port e Myllin depression. In the last-mentioned locality, as it reaches the lower part of the slope a few foreign stones make their appearance, at about 250 feet above sea level; this is best seen in a deep gutter which descends the slope from a house by the roadside near Ballasaig, 600 yards S.S.E. of Lewaigue, where there is a section showing about 10 feet of slaty-rubble drift with some extra-insular pebbles; and a 4-ft. boulder of grey Galloway granite, and another of coarse granite not unlike that of Shap, 3 feet in diameter, lie in the bottom. At the foot of the slope red clay is seen, as previously described (p. 444). Similiar conditions prevail all along the eastern flank of the massif; but south of Laxey the intermingling of the foreign with the local material becomes more intimate and extends farther inland.

RNAH
LLEY.

Between the hamlet of Cornah (Sh. 8) and the coast the valley-floor is flat and fringed with gravel terraces, except at one place just above the confluence of the Rhenab tributary, where the stream seems to have missed its preglacial channel. This part of the valley is thinly lined on both sides with local drift, in which a streak of red clay was noticed about $\frac{1}{2}$ mile from the coast. The rocky glen above Cornah is clear of drift until we approach Corran, where there is a little river-flat in which some recent changes have been made in the water-course. West of Corran we enter a broad glen running back into the heart of the hills, which appears to be an older feature than the lower valley. Local drift of the usual hill-type is thinly overspread on the northern side of this glen up to 1,000 feet or more above the sea-level, but on the steeper southern side is more restricted. As is generally the case in upland valleys of this character, the present stream has almost everywhere reached the rock-floor, and the drift forms grassy banks somewhat above the valley-bottom which constantly tend to slip. On the high-lying slope near Park Lewellyn (Sh. 8) there is a group of large blocks of slate and greenstone which, in their natural position, are rather suggestive of a small valley-moraine; they may, however, have been artificially brought together for some purpose in prehistoric times. If morainic, their occurrence is exceptional, as indications of valley-glaciers, so common in Scotland and Wales, are conspicuously wanting in the Island.

Returning to the mouth of the Renab tributary, we find for 200 or 300 yards on the northern side of that stream a high cliff of slaty till, while the opposite side is a bare rock-slope. Although the Dhoon Granite crops out on the crest of the hill, $\frac{1}{4}$ mile to the southward, no fragment of it was found in this drift. Toward the head of one of the branches of the stream, which descends directly from the granite near Ballig, one or two boulders of this rock were, however, noticed. Another of its branches, 150 yards south of Trinity Church, exposes slaty till 16 feet thick, resting on decomposed red and yellow slate-rubble. This material continues in a broadish strip northward to Corran, being proved to a depth of 12 feet in a well at *Ballacorteen* 400 yards E. of the church; and also extends southward, along a shallow depression, across the granite outcrop, to the head of Dhoon Glen; leaving Barony Hill to the eastward and Slieau Ouyr and Slieau Ruy to the westward practically free from drift.

DOON
GLEN.

To the southward of the granite, while slate still constitutes the main ingredient of the glacial deposits, the igneous rock has contributed freely, especially to the upper or more rubbly portion. There is no drift in the deeper part of Dhoon Glen, but a thick mass fills its higher valley and is exposed in sections 30 to 40 feet deep on both sides above the upper high-road. A mining adit 70 yards long, driven northward from the valley a few yards west of this road, is said to be entirely in till. On the slopes above *Rhenny* the drift becomes thin and rubbly, and in this form extends

over the western part of The Dreem at an elevation of 900 feet, descending thence into the Laxey basin. The eastern portion of The Dreem is without mappable drift, but boulders of Dhoon Granite are plentiful there. South of The Dreem thin drift covers the upland, but fades out on the brow of the Laxey valley.

Near the mouth of Laxey Glen, on the northern slope east of Minorca (Sh. 11), there is a well-defined terrace of slaty gravel with streaks of red clay, 50 to 60 feet above the present stream; and portions of a similar terrace are traceable on the opposite side, just above the confluence of Glen Roy. These are no doubt equivalent to the 'Late-glacial Flood-gravels' of the northern glens, and have probably at one time been connected with a delta outside the valley-mouth, which has been removed by the sea. Up to its junction with *Glen Agneash* the river possesses a terraced alluvial flat, and has not reached its pre-glacial floor; but above that point its alluvium contracts, and solid rock is constantly seen in the stream-bed. Irregular strips of rubbly drift, in places covering hard slaty till, line the valley on both sides, generally a little above the bottom, up to its head, filling the high cols north and south of Snaefell to a considerable depth. A large boulder of Dhoon Granite lies at the edge of the alluvium 500 yards above the Agneash confluence; but none was seen higher up the valley, and the fragments of 'contact-rock' observed by Mr. Kendall on the flanks of Snaefell¹ are of local derivation. This absence of Dhoon boulders west of the granite outcrop shows that the south-westerly current in the ice under the lee of the Island was subordinate to the general south-south-easterly movement of the main sheet which passed over the summits.

At the mouth of *Glen Agneash* there is a bank of coarse flood-gravel; and the drift has been almost denuded from the lower part of this valley, but lies deeply in places on its upper slopes, as for example in the banks of the Glen Drink feeder, when there is slaty till 20 feet or more thick. It is to the eastward of this place that the Dhoon Granite blocks begin to be numerous. The patch of drift on the high moorland south-west of Slieau Lhean is chiefly of the rubbly type. Glacial striæ on this moorland and on the high ground on the southern side of Laxey Glen are recorded in the List (p. 476).

In Glen Roy the drift is mostly confined to the northern bank where the side-ravines frequently expose deep sections in hard slaty till; this is 40 feet or more in thickness near the head of Glen Roy itself at 800 feet above sea-level, and in the more northerly branch rises to 1,220 feet in the pass between Carn Gerjoil and Mullagh Ouyr, and descends the opposite slope along the Creg-y-cowin feeder of the Baldwin River (Sh. 10). No boulders of Dhoon Granite were observed in Glen Roy or its tributaries, though there are some derived from the elvan-dykes associated with this granite, which cross the heads of the northern feeders of the glen (p. 367).

South of Glen Roy, the little undulating plateau west of Christ (Lonan) Church is thinly overspread with drift, which apparently contains a few foreign blocks as well as Dhoon Granite, judging from the stones collected from the fields, and from the presence of a few boulders, including one of grey (Scotch ?) granite 2 ft. in diameter in a field 300 yards east of Hoanes (Sh. 11).

At *Poolvilla*, 700 yards W.S.W. of Christ Church, at 500 feet above sea-level, there is a little dry gully, excavated partly in slate, for which the present drainage can scarcely be held responsible. The narrow moorland-spur running eastward from Slieau Meayl to Barroose, a mile inland from Garwick Bay, is notched across by several dry gullies of similar character to those which have been described on the north-western flank of the massif. These are slightly developed in two or three places between *The Skoryn* and *Cronk Garroo*, at 800 to 900 feet above sea-level; a better example is seen at *Caurhenny*, east of *Cronk Garroo* (Sh. 11), at a little over 700 feet; and another, smaller but in some ways more remarkable, half a mile farther east, at between 500 and 600 feet, near the farmstead of Barroose. The last-mentioned, in which the slate has been quarried,

LAXEY
BASIN.

DRY
VALLEYS
EAST OF
SLIEAU
MEAYL.

¹ Yn Lioar Manninagh, vol. i., p. 401.

does not cross the ridge, but runs more or less parallel with it, and ends off abruptly on the slope. A little below its mouth there is a lenticular mound of slaty gravel which may possibly be connected with its erosion. The ridge, from its position athwart the general axis of the Island and from the presence of wide tracts of lower ground on both sides, would be likely to emerge at the margin of the waning ice-sheet in the path of streams flowing southward over the ice; and, as already stated, it is difficult to understand how otherwise valleys of this character could have been excavated.

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On the gentle southern slopes of the ridge the head-waters of the Groulle River are collected. The most westerly branch, known as the *Ballacottier River*, rises directly under Slieau Meayl and flows southward in a broad hollow thinly covered with clayey local drift. In the lower part of its course, 700 yards above its confluence with the main stream, it reveals red stony clay, unlike the grey till in its upper reaches; the included stones, however, seem to be all local. At Low Ballacottier (misengraved Ballacollie on the old one-inch map) at 400 ft. above O.D. there is an ill-defined patch of yellow loamy sand; and in a little gully 100 yards farther south rather pebbly boulder clay is exposed, in which besides the usual local stones a few small foreign pebbles were noticed, including one, an inch in diameter, of the Ailsa Craig rock. At about the same elevation a mile farther west, in the drainage basin of the Baldwin River, the extra-insular material is still better represented, as will subsequently be described (p. 455). It indicates the invasion of the area by an ice-lobe laden with foreign material, which probably passed up the broad shallow depression westward of Clay Head. The electric tramway follows this depression and on the S. slope of *Glen Gaune* (Garwick), near Ballig, reveals slaty gravel and sand, with a sprinkling of foreign pebbles; similar material, mixed with slaty till, is also exposed between Ballameanagh Beg and Baldroma Beg (Sh. 11); and again on the north side of Groulle Glen, where it rests on a glaciated surface of slate. The undulating ground east of the tramway is drift-covered up to Ballacreggan, Ballakilley and Ballavarane; and is trenched by a broadish drainage hollow in which some alluvium has accumulated. Scattered over this track, along with numerous Dhoon Granite boulders, are many of extra-insular origin, including Galloway granite, coarse Silurian grit, porphyrite, diorite, etc. These are especially noticeable in the fences around Baldroma Beg, where one of the blocks, 2½ feet in diameter, in a fence 370 yards S.W. of the house, resembles the altered tuff of the Lake-district Borrowdale series.

To the westward of the tram-line, north of Groulle, extra-insular ingredients are rare or absent, the ground being overspread by a sheet of hard slaty till, which is exposed in a bank 30 to 40 feet high on the north side of the stream 150 yards east of the Laxey highroad-crossing at *White Bridge*. North-west of the road, between Ballakilmartin and Begoade, we find in the fields and fences scattered blocks of the peculiar igneous rock to which reference has been made in another chapter (Chap. IV., p. 160); these increase in abundance towards Ennamona and *Caunrhenny* where, as previously stated, it is probable that an outcrop of the rock may occur, thinly covered by rubbly drift. These boulders were at first thought to be of extra-insular origin.

On the southern side of Groulle Glen, a little eastward of the highroad, a shallow depression leads into an alluvial hollow which curves round at Onchan (Conchan of new Ordnance map) and drains into the sea at *Port Jack* (Sh. 14). The alluvium consists principally of clayey wash, but is said to contain peat with wood east of the dam at Onchan. The depression probably marks a Late-glacial flood-channel. It is bounded on both sides by thin slaty drift, through which the rock protrudes in the bank north of Onchan Church.

We will now return to the western side of the Island, and work eastward across the drainage basins which discharge into the central valley.

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The rivulets which descend to the western coast at *Glion Shellan*, *Glion Cam* and *Glion Broigh* (Sh. 6) have each their source in a little basin of slaty drift. In the second of these, the flatter part of the basin has a floor of alluvial wash thinly covered with peat. Small areas of this character are

common on the uplands, and have probably at one time been occupied by shallow tarns, though none now exists in this condition. The subsoil in these tracts is usually a cold wet clay full of bits of vein-quartz, the relics of the decomposition of local slaty wash; and Manx farmers reckon such land, which they recognise by the abundance of the "white stone" (quartz) as the worst in the Island (p. 569). On my field-maps I applied the term "Colby Wash" to ground of this description, from the district in which I first encountered it. Its origin may be assigned to the washing of bare drift-slopes by heavy rains immediately after the recession of the ice-sheet, and before the growth of vegetation (p. 413). The absence of tarns among the hills at the present day is somewhat unusual for a glaciated district, but may be explained by the short course and steep fall of the streams, by which they have been enabled to break through the drift-barriers and to re-excavate their filled-in preglacial channels with rapidity.

"COLBY
WASH"

In the sprinkling of drift-rubble which covers the slopes of slate in this neighbourhood, a few foreign pebbles may be observed, among which a fragment from Ailsa Craig was noticed at about 500 feet above sea-level east of Knocksharry. To the east of this hill there lies another upland drift-basin with a flat of "Colby Wash," which drains to the valley of the Neb below Laurel Bank. Glacial striæ occur at Staarvey, Lambfell Moor, Beary Park and other places in the vicinity of the Neb, as recorded in the List (p. 477). The next depression eastward, through which runs the main-road from St. John's to Kirkmichael, has been mentioned before in connection with peculiarities in its drainage (p. 8). Its northern portion, draining to Glen Moor, is occupied by slaty till, while the water-parting between the north- and south-flowing streams lies in a strip of alluvial wash underlain by rubbly drift, like the basins above described.

The main head-waters of the Neb are in drift-filled hollows on the southern slopes of Sartfell. In the east branch or Rhenas River (Sh. 7), there are good sections showing 40 to 50 feet of slaty till capped with slaty rubble, at about 1,000 feet above sea-level, just below the col east of Cronkdoo, as well as at several points lower down the stream. The feeder north of Cronkdoo starts high up on Sartfell in a bare coombe-like hollow with cliffs of slate, but has banks of drift a little lower down the slope. South of Little London the river runs for the most part on bare rock, bordered here and there by strips of alluvium, down to the mouth of Glen Helen. The steep western slope of the valley is also free from drift, but on the opposite side the bank has a capping of local till and rubble which extends eastward over most of the enclosed ground and moorland up to the spurs of Colden and Lhargee Ruy, except where eroded through by the side-streams. A small quarry near the edge of the moorland, 1,000 yards E.S.E. of Ballashimmin, reveals 5 feet of till resting on a glaciated surface of slate, with striae in two directions, both somewhat unusual, viz., W. 30° N. to E. 30° S., and E. 20° N. to W. 20° S., the ice having evidently suffered local deviation in this confined basin. The drift, covered with 2 or 3 feet of hill-peat on the watershed, sweeps over the ridge into the basin of the Glass river between *Slieau Maggle* and Colden, and again between Colden and Lhargee Ruy, at elevations of 1,200 to 1,300 feet.

BASIN
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Below Glen Helen the deep valley is free from drift on the western side, but has hard slaty till and rubble banked thickly against its eastern slope. A brickyard on a rather extensive scale was started in this bank 600 yards above the bend at Ballig, but the material seems to have proved unsuitable; the section here shows 20 feet or more of bluish slaty till. To the north and south of this place the valley-spurs are capped with flood-gravel, 12 to 15 feet thick, probably the relics of a high terrace of Late-glacial age connected with the great terraces which line the central valley around the mouth of the glen (p. 410). No trace of foreign material was found in any part of the basin above the termination of the glen at Ballig; below this point the river occupies an alluvial flat, but erodes the northern bank just before issuing into the central valley, revealing 8 feet of stratified stony rubble resting on 15 feet of slaty gravel belonging to the higher flood-terrace. In the bed of the river below this section red pebbly clay containing masses of crushed slate, foreign stones

and many fragmentary marine shells is revealed, while slate in place is seen a few yards farther eastward. The shelly clay is like that in the river-bed near Peel (p. 457).

Leaving for the present the consideration of the central valley itself, we pass eastward on its northern slopes into the little drainage basin of the Greeba River. This is covered with a thin but persistent sheet of slaty drift, up to the slopes of Beary Mountain on the north and Greeba Mountain on the east. The latter hill shows glacial striae a little to the east of the summit, at 1,268 feet above O.D.; and others along with the characteristic rounded surfaces, indicating movement from the west and north-west, on the top of the crags overlooking the central valley. Greeba Glen is for the most part clear of drift; but in the bed of the stream, 300 yds. above the mill, a 3-ft. boulder of grey (Galloway?) granite was noticed, and a little lower down another of pebbly grit which did not seem to be insular. These have no doubt been transported eastward along the central valley by the ice-lobe previously described (p. 351). The singular effect of the old delta of flood-gravel at the mouth of Greeba River in diverting the present drainage has already been noted.

OF Bordering the central valley east of Greeba Mountain, there is again a broad drift-covered incline, out of which rise islands of bare slate in *Cronk Breac* and *Cronk ny Mucaillyn* (Sh. 10), while in several other places the sheet of slaty till and rubble is so thin that the rock peeps through. Indeed in all tracts of this kind in the Island, while on first impression it may appear that the solid rocks are buried deeply, one finds on closer investigation that the smoothing down of the surface has been effected with great economy of material, and that only exceptionally, in the deeper hollows, have the glacial deposits accumulated thickly. Hence 'live-rock' crops out, in little patches too small to map, in all sorts of unexpected places. The drift-mantle is therefore far more ragged than appears on the published map. Sometimes, as in this tract, the positions of a few of the rock-exposures are indicated on the map by dip-arrows or other rock-symbols.

On the slope north of Eyreton Castle an unusual number of large boulders of actinolitic greenstone (p. 311) have been ploughed out, and now line all the fences up to Braid; and are equally plentiful on the opposite slope leading into the West Baldwin (Glass River) valley, around Ballalough and again near Ballaquine.

The principal known exposures of dykes of this character are near the heads of the Glass and Baldwin valleys, 4 miles to the northward (pp. 157 and 159), but there may of course be nearer outcrops concealed by drift. In any case, the blocks form a well-marked train crossing the ridge in a N.N.E. to S.S.W. direction, in agreement with the trend of the glacial striae of the neighbourhood. On the same slopes $\frac{1}{2}$ mile farther east, near Nab and Ballakelly, while the greenstones diminish, boulders of pale micro-granite of the Foxdale elvan-type (p. 158) become plentiful; and though somewhat intermingled, a parallel train of the latter may be traced down to the central valley near Ballabeg and Ballahutchin. These have no doubt been derived from the dyke which is exposed at Ballachrink in the West Baldwin valley, though not necessarily from this particular part of its outcrop. Still farther east the boulders are principally of quartz-veined grit, like that seen in place north of Mount Rule and on the moorlands east of the Baldwin River. The drift with which all these boulders are associated is hard slaty till; and this material lines the northern side of the valley down to Union Mills.

IN In the lower part of the valley drained by *Avin Darrayh* (Sh. 10) which joins the River Glass at Baldwin, we find an unusual quantity of local till, scarcely any rock being exposed below Cregwine. Above this place there is only a narrow strip of drift in the glen until we reach its head at *Braid ny Scarrag*, at about 1,100 feet above O.D., where it is again banked deeply and sweeps over into the Neb basin as already described. Similar conditions occur at the head of the Injebreck River on the northern side of Colden Mountain, but this stream flows over bare rock for some distance above its junction with the Glass.

The upward margin of the drift around the head of the main branch of the Glass, between Injebreck Hill and Beinn-y-Phott, is ill-defined, fading off on the higher ground, as usual, into a sprinkling of slaty rubble containing a few scratched stones. In the valley there is much slaty till; above Injebreck the stream has cut through this to its old floor, but below that place the glacial material occupies parts of the valley bottom, and is exposed in high banks on the eastern side, both on the main stream and in transverse gullies. One of the best of these sections is the river-cliff 300 yards S. of Ulican (Sh. 10), which exhibits from 40 to 50 feet of till interbedded with rough slaty gravel. This drift extends westward up to the foot of the Awhallan crags, on which there are excellent glacial striæ (see List, p. 477); and eastward, though not quite continuously, across the dividing ridge into the East Baldwin depression. Below Injebreck traces of fluvatile gravel-terraces are visible here and there in the bottom of the valley, the higher of which probably correspond to the more conspicuous platform below the confluence of the Baldwin River which attracted the attention of Macculloch¹ and Cumming² (p. 405).

The conditions in the East Baldwin valley resemble in all respects those of West Baldwin, except that the drift is not so thick in the bottom of the glen; wherefore the stream runs for longer on a rocky floor, and its alluvial flats and terraces are confined to lower reaches than in the sister-valley. EAST
BALDWIN
VALLEY.

Its eastern feeders, the *Creg-y-cowin River* and a nameless stream 700 yards farther south, rise in basins deeply filled with glacial material, and afford interesting illustrations of the post-glacial erosion of these deposits. On the moorland-ridge of Slieau Ree to the east of the valley, glacial striæ were observed in several places (see List, p. 477). The eastern slopes of this ridge are thinly overspread with drift, apparently all of local origin, in which small sections are revealed in places in the gullies that occur at the head of a little stream (*Sulby River*) tributary to the Glass. The rising ground east of this stream is also more or less drift-covered; and on the southern part of this tract, between Abbeylands and Glenville, at 300 feet above sea-level, a section occurs which deserves especial notice, since it shows an admixture of extra-insular material with the local detritus. This is revealed in a shallow clay-pit 500 yards west of Glenville, from which material was dug for use in the construction of the Douglas water-works reservoir on the Groulle River; the section visible in 1896 showed 2 feet of slaty gravelly clay of 'Colby wash' character (p. 453), resting on 6 feet or more of dull red clay with stones of which the majority and the larger were local, but with a fair sprinkling of foreigners. GLENVILI

Among the local boulders was one of greywacke, 6 feet in diameter; the extra-insular stones included fragments of grey (Galloway ?) granite; red sandstone and grit (rather plentiful); Carboniferous Limestone, etc. Specimens of the Liassic fossil *Gryphaa incurva* were said to have been obtained in this pit by the workmen, but their authenticity seemed very doubtful.

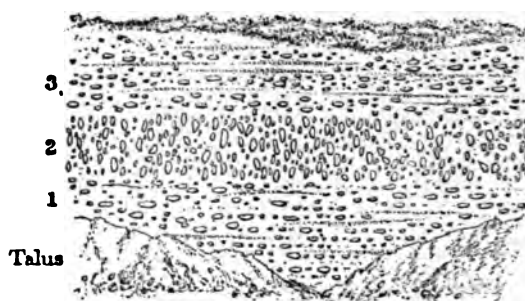
The little glen to the S.E. of this exposure revealed no clear section; but a brickyard by the side of the highroad at *Highton*, 300 yards S. of the glen, showed 10 feet of mixed slaty clay; in this a few red sandstone pebbles were noticed, and possibly other foreigners might have been obtained by longer search. This drift was rather gravelly at the top, and thinned off southward upon a bank of slate. A slate quarry 400 yards east of Willaston (Sh. 13), $\frac{1}{4}$ mile S.E. of the section last described, is capped by gravelly drift, 2 to 3 feet thick, containing numerous foreign pebbles; and the same admixture probably prevails in most of the material which covers the slope between Cronk-ny-Mona (Sh. 10), where the bare rock is seen, and the valley of the Glass. Where thin, such drift weathers into a reddish or yellowish stony loam, differing from the soil of the unimixed slaty boulder-clay. It is frequently difficult to decide whether it is least misleading to map such material as gravel, or as boulder-clay,—a difficulty often still more acute in the case of the mixed drift south of the central valley.

¹ "Western Isles," vol. ii., p. 525.

² Quart. Journ. Geol. Soc. vol. ii. p. 338.

ER PART In the valley of the Glass below its junction with the Baldwin, high
THE banks or cliffs of till and partly-stratified drift extend along the eastern side
LEY OF of the river-flat down to Tromode. A section in the upper part of this
GLASS. bank 300 yards N. of the dam of Tromode Mills showed 30 to 40 feet of stratified coarse slaty gravel and loamy sand, with bouldery loam towards the top. In some of the gravel beds in this section the pebbles were arranged with their longer axes vertical. One hundred yards farther south, firm slaty till is seen at the foot of the bank, with gravelly drift above. A little below this place the river has missed its old channel and excavated a trench in slate, as described in a previous chapter (p. 161). The section where the present bank cuts across the abandoned eastern loop opposite Ballanard shows slaty flood-gravel resting on warp and silt, with boulder clay probably concealed under the talus slope. Slaty till is seen again under the gravel terrace in the little side-ravine 500 yards S.E. of Tromode. On the western side, the river-flat south of the confluence of the Baldwin and Glass is fringed by a high-level terrace, which, like its equivalents in the Baldwin valleys, borders a more or less drift-covered slope. This terrace is interrupted by a bluff of slate at *Sir George's Bridge*,

FIG. 107. Section at the top of the valley bank, 400 yards south-west of the *Purt-ny-shee*, near Douglas.



- 3 Late-glacial flood-gravel ; pebbles, chiefly of slate, fairly well rolled, lying flat ; about 3 feet seen.
- 2 Grey loamy layer, with most of the pebbles vertical ; 1 to 2 feet.
- 1 Slaty gravel and wash like No. 1, with the pebbles flat.

near Oatlands (Sh. 10), but sets in again a little below, and continues up to the ravine at Tromode. It is represented on the opposite side of the valley by the gravel which covers the southern spur at the confluence of the *Sulby* stream. Opposite Castleward the terrace is composed of thin clayey rubble resting on slate, with little or no clean gravel. It falls southward from 200 feet above O.D. where first seen, to 100 feet at Tromode, but does not quite keep pace with the present fall of the river, and is therefore highest above the stream in the lower part of its course.

Below Tromode the valley bottom expands suddenly into an alluvial flat 200 to 300 yards wide, and 40 to 50 feet above sea-level. The opinion is generally held in the neighbourhood that this alluvial flat marks a silted-up estuarine inlet, an idea recorded by Cumming,¹ repeated in the guide-books, and fostered by the name, *Purt-ny-shee*, by which the place is known. The flat is however evidently of fluvial origin, and is too high to have been entered by the sea even during the Raised Beach period. On its western side the continuation of the high terrace above-described

¹ "Isle of Man," p. 18.

may be traced down to its junction with the central valley, where the edge of the terrace is 40 feet above the river-flat. Sections of this terrace in the steep bank S.W. of Purt-ny-shee farmstead exhibit in places 20 feet of slaty gravel, with loamy bands in some of which most of the flatter pebbles are vertical even when underlain and overlain by beds in which such pebbles are horizontal, as shown in Fig. 107.

Traces of the gravel terrace are also seen, resting on a high bank of till, on the eastern side of the valley between Tromode and Purt-ny-shee; but south of the latter place they disappear, and the stream impinges upon a bank of slate. From the form of the ground and the position of the gravel, it seems not improbable that the drainage of the valley may at one time have found more direct access to the sea in Douglas Bay, in the direction marked by the shallow depression due east of Purt-ny-shee, to which reference has been made in describing the Douglas area (p. 446).

The spur of rising ground between the valley of the Glass and that of the Balla-Dhoo below Union Mills is almost wholly drift covered, and sometimes **BALLA-FLETCHER.** apparently to a considerable depth, but there are few sections. West of the road between Oatlands and Union Mills, slaty boulder-clay is the chief constituent, and no foreign ingredients whatever were found. East of the road, gravelly and sandy material predominates, with a sprinkling of extra-insular pebbles among the slaty debris, and the surface is more uneven and mounded. A small sand-pit in this tract 350 yards W. of Cronkbourne House showed (in 1896) 12 to 15 feet of cross-bedded fine gravel and loamy sand. Former pits of larger size adjoining the main road 400 yards W.S.W. of this place are now disused and obliterated. Towards the southern end of the spur the ground becomes stiffer, and has been mapped as boulder-clay.

Central Valley—Peel to Douglas.

The general description of the drift and alluvia of the central valley given in preceding chapters (Ch. I., p. 8, Ch. IX., p. 349, and Ch. X., p. 409), will be supplemented by a few additional details, without repeating the facts already recorded.

Between Peel Harbour and the rock-gorge at Glenfaba the Neb is fringed **PEEL.** on the east by a low alluvial flat, *Close Chiarn* of the six-inch map (Sh. 9), which is conterminous with the strip of Raised Beach at Peel, and may be in part estuarine. This is bordered on the east by a high bank of drift of the extra-insular type, best exposed in the road-cutting leading to Glenfaba Bridge, consisting of red sandy boulder-clay, associated both above and below with sand, loam, and gravel. The bed of the river 300 to 400 yards S. of Peel Station reveals patches of contorted red pebbly clay and loam with foreign stones and many fragmentary marine shells, including *Leda pernula*, *Tellina balthica*, *Trophon clathratus*, etc., which appears to rest directly on crushed slate, and must have been deposited against the cliff-like rock-slope which forms the western bank of the river beneath Peel Hill. A large excavation into this bank at the brickyard 150 yards farther south, where some of the drift still adheres to the slope, showed (in 1897) 10 to 20 feet of slipping slaty rubble, mixed with red clay and drift-gravel containing pebbles of flint, Ailsa Craig riebeckite-rock, granite, etc., and some scratched stones. This drift rested on the crushed and decomposed shaly blue slate, which is ground up and made into bricks.

It has previously been suggested (p. 410) that at Glenfaba the buried pre-glacial valley probably lies to the eastward of the present gorge; and evidence in favour of this view is furnished by the report (see p. 279) that 90 feet or more of "soft clay, gravel and clay mixed, and then boulder-clay," were passed through in a boring for coal made in 1873 a little to the eastward of Glenfaba Mills. This boring does not appear to have struck solid rock until below present sea-level, although in the adjacent river-bank the rock is seen at 50 to 60 feet above O.D.

The undulating platform of Extra-insular drift extending inland from Peel to the foot of the slate hills at Lhergydho and Poortown is composed

for the most part of low sandy and gravelly mounds, but red stony clay comes to the surface on the rise between Ballaquane and Ballagry, and slaty clay covers the lower slope of the solid hills. The platform is trenched by several drainage channels, now almost dry, falling southward to the Neb. The occurrence of little basins in this tract has been previously noticed in describing the elk-remains found at Close-y-Garey, but the most conspicuous example, at Ballalough, deserves further mention. This is a pit-like hollow about 200 yards in diameter, surrounded to a height of 40 or 50 feet with steep banks of sand, gravel and a little clay, except on the south-west where one of the drainage channels just referred to leads out from it towards the Neb. The bottom of the basin is still boggy, but contains a dry mound which is not unlikely to be artificial, like the so-called "Fort" at Lagagh Moor (p. 432). Immediately to the south-east of this hollow rises *Croak Lheannay*, a little isolated hill of bare slate (p. 155); and we may suspect that the deposition of the drift may have been so modified in some way by the vicinity of the rocky hillock as to produce the depression. A smaller basin lies 200 yards farther north, with another, still smaller, beyond it, the three forming a broken chain in the direction of the drainage-slope.

The upper gravel terrace on the northern side of the Neb east of Ballawyllin is in places only thinly overspread with slaty gravel, with an eroded surface of glacial clay. This clay has been dug for brickmaking both on the terrace and in the upper bank of drift which bounds it, but the works were not in operation during the survey of the area.

K
RICK.

On the south side of the valley around Kirk Patrick, above the terraces elsewhere described (p. 410), clayey drift containing an admixture of local and foreign detritus sweeps through the low col leading to Glen Meay; at (Gordon and Rheahymoor this is overlain by terrace-like strips of gravelly material, and in the valley bottom by alluvial wash, indicating former drainage through the gap. The manner in which the lower layers of the ice-sheet laden with foreign material were pushed forward into the embayment of the hills in this neighbourhood has previously been discussed. While the greater portion of this ice escaped through the opening at St. Johns and up the Archallagan slope (p. 351), or passed out at Glen Meay by the above-mentioned col, some part seems to have been pushed up the western slope of Slieau Whuallian, where the gradient is comparatively gentle, as foreign material is associated with slaty drift in the patches preserved around the heads of the little glens high up on the ridge, and passes at Eairy over the watershed into a gully descending to Glen Moor. A boulder of grey (Galloway?) granite, measuring 5 feet by 3 feet by 2 feet, lies in the ravine above Ballacossnahan (Sh. 9), 400 yards S. of the Peel reservoir; another, of purple grit, 5 feet in diameter, at the head of the glen due south of Ballaspet, with others lower down; and Mr. Kendall records a 3-ft. block of Galloway granite on the ridge of Slieau Whuallian itself.¹ The boulders are most numerous and largest, however, below Eairy, in the above-mentioned rocky gully descending southward into Glen Moor, at 500 to 600 feet or more above sea-level, where among others noticed were one of grey granite, 6 feet by 5 feet by 4 feet, and one of pebbly grit, 6 feet by 4 feet by 3 feet. This gully is one of those which cannot be explained by the present drainage and must date back to Late-glacial times. Glacial striae in several places on Slieau Whuallian show that the summit of the ridge has been crossed by an ice-flow from N.N.W. (see List, p. 477).

LAU
UALLIAN

DALE.

The character of the drift in Foxdale has previously been outlined (p. 350 and p. 370). The best sections are in the lower part of the glen and at the head of its western feeders south of Slieau Whuallian, the upper part of the main valley containing only a thin rubbly covering on the slopes, with bare rock in the stream-bed. A 4-ft. boulder of Galloway granite was observed near the east bank of the river 400 yards below the road-crossing at the mines, and two or three others of smaller size lower down the glen, north of Ballanas, where the slaty drift is intermingled with foreign material (see Fig. 94, p. 350). To the eastward similar boulders are scattered plentifully on the upland around the head of Glion Darragh,

¹ Yn Lioar Manninagh, vol. i., p. 409.

out blocks of the local granite alone were seen on the moorlands west of Foxdale.

The slopes above the fans of flood-gravel lining the central valley east of Foxdale have a thin covering of yellowish sandy drift, containing both local and foreign pebbles. This is sparingly exposed in the occupation roads south-east and east of Kennaa (Sh. 9); it has been coloured as 'boulder-clay' on the map, but scarcely falls under that designation; and the rather more sandy material occurring in the same position farther east, around Rhenny (Sh. 10), is so far removed from boulder-clay that it has been coloured as 'sand and gravel.' In cases of this kind, where the lithological characters hang upon the border-line, it must be understood that the strong contrast in the conventional colouring of the map may represent only a slight difference in the actual composition of the deposits. A few boulders of Galloway granite and other extra-insular rocks accompany this sandy drift and mark the path of the ice-lobe previously discussed (p. 350). The crest of the slope is for the most part bare of drift, but on the plateau beyond we again find a covering of yellow loam with an admixture of local and foreign stones, best seen in the road leading from Ballacurry to the Old Cornelly Mines, and in the drainage-trenches of Archallagan plantation. No drift now remains in *Glion Darragh* (otherwise known as Ballacurry Glen), but numerous large foreign boulders strew its channel, of which a rounded block of grey (Galloway?) granite 8 feet by 6 feet, at the fork below the mines is perhaps the finest example.

On the northern side of the central valley, a little tract of moundy gravel at Ballacraigne, at the mouth of the low col leading into the ravine of the Neb, deserves mention. Like the adjacent gravel-platform of slightly newer date, it probably denotes the passage of flood-waters from the upper glen through this now dry gap during the melting of the ice.

The drift on both sides of the valley contracts eastward towards Greeba, **EAST OF GREEBA.** and disappears altogether in the narrowest part of the pass opposite *Cregacable*, where the rocky bluffs come down to the alluvium for a space of 40 or 50 yds. To the E. of this, sloping banks of drift once more border the depression, that on the southern side, which continues up to the mouth of *Coollingill* (Sh. 10), being again in part composed of yellow sandy loam. A 4-ft. boulder of grey Galloway granite was noticed at the lower margin of this bank 480 yards S.W. of Cregbeg. The head of *Coollingill* reaches back to Archallagan, and contains loamy drift with foreign stones at 600 feet above sea-level. Similar material extends southward into the little basin which gives rise to the stream flowing to the central valley at Ellerslie; and occasional extra-insular boulders, along with many from the local micro-granite dykes, may be seen in the fences around and to the east of Eairyjora and Eairykellag (Sh. 13) at elevations up to 500 feet. At Garth in the lower part of the basin this drift becomes assorted into stratified sand, gravel and stoneless warp; and an irregular strip of similar material stretches down the depression N.E. of Slieau Chiarn to the mouth of Ellerslie Glen. **ELLERSLIE** A small sand-pit in this strip 350 yards west of Ballingan showed 6 feet of yellow sand with small local and foreign pebbles scattered as in a boulder-clay. A rock-surface exposed at the new buildings 60 yards E. of the pit bore glacial striae in two directions (p. 479); the one set corresponds with striae on Slieau Chiarn, and represents the local flow on the leeside of the hills; the other agrees with those on Archallagan and Slieau Whuallian, and indicates the main flow. Below Ellerslie the drift on both sides of the central valley seems all to be of local origin, until we pass Union Mills; it is, as usual, deeply banked on the northern slopes, and thin or absent on the opposite side. Below Union Mills the south-western slopes, above the flood-terrace (p. 411) and below the outcrop of the slate, are sparingly covered with indefinite rubbly loam; this has been coloured as 'boulder-clay', except where it forms distinctly gravelly mounds as in the patch between Kirby and Farnhill and again at Pulrose (Sh. 13). The drift of the opposite side of the valley has already been described (p. 457).

The remnants of a flood-gravel terrace, probably equivalent to those of the **MIDDLE RIVER.** Glass and the Dhoo, are seen in the lower part of the valley of their con-fluent, the Middle River, up to its sharp bend above Kewaigue. Its western

slope south of Middle is capped by a moundy belt of rubbly and sandy slate-gravel with some foreign pebbles, which follows the trend of the valley up to the above-mentioned bend, but then crosses it and runs up into a depression leading to the coast at *Keristal*, north of Port Soderick (p. 463), no doubt indicating a glacial drainage-course. To the east of the valley, the patches of drift running up into the depressions at Nunnery Howe and Ballaslig though still rubbly are of a more clayey character. Both varieties are exposed in railway-cuttings between Douglas and Port Soderick. In the upper part of the Middle River basin, north of Richmond-hill, there are several small exposures of slaty till, while an ill-defined patch of local gravel occurs south of Ballabunt.

The drifts of the eastern extremity of the central valley required no further description than that already given (pp. 456-7).

SOUTHERN DIVISION.

(Parts of sheets 9 and 13, and sheets 12, 15, 16, 17, 18 and 19, of 6-inch map.)

Western Coast south of Peel.—Between Peel and Contrary Head a mere sprinkling of drift-pebbles on the steep hill-slope above the cliff and some striae on the top of the ridge (p. 477) are the only indications of glaciation. On Contrary Head itself, a little red boulder-clay and gravelly drift with local and foreign stones has lodged; and is associated with striae parallel to the cliff-line, which show that the general contour of the coast has not altered much since Glacial times. Narrow strips of similar drift hug the crest of the cliffs southward to Glen Meay, running a little way inland in a gap in the ridge S.W. of Knockaloe Moor (Sh. 9), and on the inward slope forming a moundy delta-like patch of sand.

GLEN MEAY
& THE
NIARBYL.

At the mouth of Glen Meay the slate-rocks sink to a comparatively low level, constituting between this place and Niarbyl Bay a sloping platform at the foot of steeper ground. Upon this platform the glacial deposits attain considerable thickness, levelling the irregularities of the old surface and rising above it north of Ballaquane into gravelly mounds. Excellent sections are revealed at the mouth of Glen Meay; and to the southward, at *Lag ny Traagh* where the drifts are 70 feet thick; and again opposite the Niarbyl. They show much variation in details, but where most fully developed the sequence is as follows—

- | | |
|-----------------------------------|---|
| 1.—Upper
Boulder-clay. | { Red sandy boulder-clay or loam; stones chiefly rounded and small, and many extra-insular, but with a few large scratched blocks; often absent, especially where the drift rises into mounds, and never more than a few feet thick. |
| 2.—Middle
Stratified
Drift. | { Rudely stratified coarse bouldery gravel, with seams of fine gravel, sand and red clay; containing slate-fragments more or less waterworn and lying flat, along with many foreign stones; thickness very irregular, up to 40 feet. |
| 3.—Lower
Boulder-clay. | { Dark grey boulder-clay; local rocks the most abundant constituent, sometimes in large blocks, but a few foreigners also; some small shell-fragments; thickness in depressions may reach 30 to 50 feet, but thins out under the Stratified Drift against slopes of rock. |

Drift of the above character, sometimes clayey at the surface and sometimes gravelly, extends inland up to the highroad between Glen Meay and Dalby, but is frequently overlain by clayey slaty rubble on approaching the steeper hill-slope. The middle division becomes thinner, finer in composition, and less moundy as we leave the vicinity of Glen Meay; which is suggestive of its material having been swept through the previously-described gap in the hills S. of Kirkpatrick.

South of Dalby the drift thins out at Barrane (Sh. 12), where the high ground again joins the coast-line. At this point a little delta of slaty gravel, at the mouth of the *Lagg River*, is intersected by the cliff; inland, in the bottom of the short coombe-like recess drained by this stream, blue slaty till has accumulated in places to a considerable depth, especially around the head of its southern branch, the *Kylley River*. In the similar but smaller hollow of Glion Mooar, a mile farther south, from which a stream leaps in a waterfall over the cliff at Gob yn Ushtey, only a little rubbly drift has been preserved; but in the bed of its stream, at 400 or 500 feet above sea-level, are several large extra-insular boulders, including one of red granite, 6 feet in diameter. The great precipitous slopes bordering the sea between this place and Fleshwick seem at first sight to offer no lodgment for drift; but this is not quite the case, since both north and south of The Stacks (*Y Slogh*, Sh. 12) a narrow strip of clayey drift with scratched stones has adhered to the seaward side of the mountain, and forms here and there a slight terrace between the higher crags and the true cliff. As we approach the Fleshwick depression, this material thickens; and fills the old valley with a mixture of slaty till, laminated clay, sand, and gravel with some foreign pebbles. Striated rock-surfaces of peculiar interest occur on both slopes, and show that a tongue of ice has been forced through the constriction; these should be studied in connection with the examples on the crest of the ridges to the northward and to the southward (consult List, pp. 478-79).

Bradda Hill though glaciated is bare of drift; but patches of till have lodged under its shelter on Bradda Head, as may be seen at the top of the cliff 350 yards S. of North Bradda Mines, where it is 12 feet thick. On this part of the headland occur numerous fine boulders of Galloway granite and other foreign rocks, one being 9 feet in diameter, another 5 feet, etc.; and associated with them are a few of Foxdale granite. Several of the former lie near the path leading from the above-mentioned mines to *Bradda West*. Mr. Kendall thinks that an Irish granite (Mourne Mountains) may be represented among the boulders which he observed in Port Erin Bay.¹ Towards Port Erin the drift thickens, again partly filling a pre-glacial hollow, which must have descended below present sea-level, as patches of till were visible on the foreshore at the northern margin of the recess in 1893 where the beach-stuff was washed aside. In the middle of the bay, where the drift is thickest, the sections are obscured; but probably consist largely of sand, gravel and laminated clay, 20 feet of such material being exposed in 1892 in an excavation at the south corner of the recess, under Ballafurt. On the opposite side, near the old Biological Station, the upper part of the cliff, above the slate, shows sandy pebbly clay and loam, partly stratified and gravelly in places, containing many shell-fragments and some foreign pebbles. Boulders of Foxdale granite were noticed in two places in this part of the bay.

South of Port Erin the drift of the coast-section is confined to small patches of clayey rubble lying thinly in sheltered places on the slate. Glacial striæ are, however, more numerous along the crest of this cliff and southward to Spanish Head than in any other part of the Island, and are frequently super-imposed in more than one direction (List, pp. 478-79).

South-eastern Coast; Douglas to Langness.

Small patches of till and gravel adhere to the northern face of Douglas Head, sometimes resting on striated surfaces of slate. The largest patch lies around Fort Anne Hotel and is exposed in a gully in the hotel grounds

¹ Op. cit., p. 406.

PORT
SODERICK

and in the adjacent road-cutting. To the southward of the Head, where the road-cuttings for the Marine Drive afford an almost continuous section in the slope above the cliff, the drift is in negligible quantity until Little Ness is passed, though glacial striæ are numerous (p. 478). At *Rebog* (Sh. 13), $\frac{1}{2}$ mile west of Little Ness, clayey drift with gravelly intercalations is banked deeply upon a sheltered slope at the cliff-top, being 25 feet thick in one part of the cutting. This gives place to gravel in the depression between Coolebegad and Port Soderick, which, as mentioned above, is probably the continuation of the gravel-belt of the Middle valley. A fine section has been opened up to a depth of over 20 feet in these gravels by the Marine Drive, showing arched-bedding, false-bedding and contortions, the pebbles being mostly of local sandy slate and greywacke, but with a sprinkling of foreigners including flint, red sandstone, porphyry, etc. The figure on next page represents a portion of this section as seen in 1892.

Among the boulders on the Port Soderick beach, the Foxdale Granite and Oatland Granite are represented, this being the most northerly point at which these rocks were observed on the east coast; blocks of extra-insular origin also occur. That the glen opening to the shore at this place has been in existence in Pre-glacial times is proved by the presence of slaty till in the bottom; this is exposed to a depth of 25 feet in south bank of the stream, 400 yards above its mouth. In the railway-cutting at Port Soderick Station, slaty till is banked against one side of a boss of rock, and slaty gravel against the other side, the gravel partly overlying and partly intermingling with the till above the boss.

ST. ANN'S
HEAD.

Southward from Port Soderick there is little or no drift in the cliffs until we round Santon (St. Ann's) Head, where some slaty till has accumulated in the recesses south and east of Mary Voar (Sh. 17). A boulder of Foxdale Granite lies in a gully in the drift of the more easterly recess, 50 yards from the shore. A remnant of the Raised Beach is preserved in this recess and in one or two others farther west. In approaching Port Grenaugh the drift forms a more continuous capping to the cliffs, and in the middle of that inlet descends below high-water mark and occupies portions of a pre-glacial channel on the foreshore. From this locality south-westward, blocks of Foxdale Granite though rarely seen in place are of frequent occurrence on the beach.

PORT
SOLDRICK

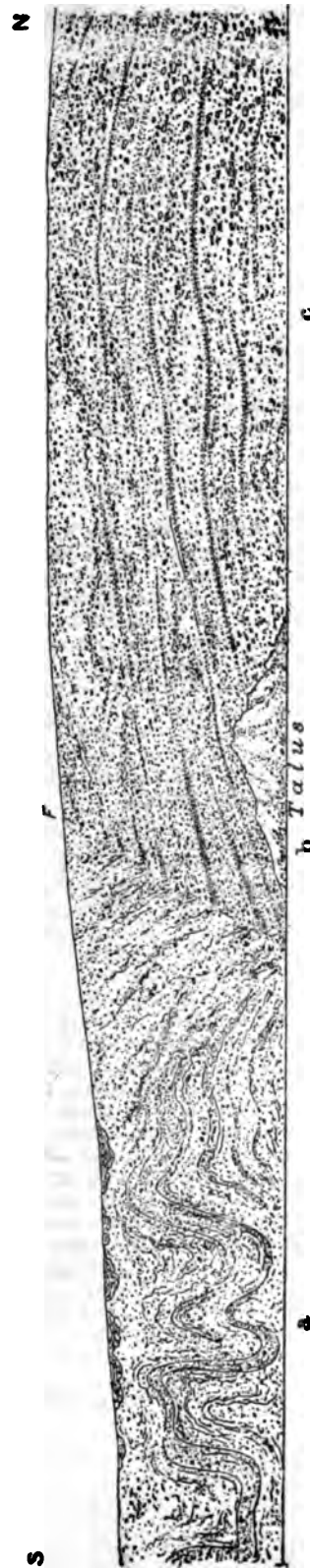
South-west of Port Grenaugh the cliffs are lower and the adjacent ground less hilly, thus affording better opportunity for drift to lodge; and we find in consequence a more regular development of the glacial deposits, though their thickness still varies greatly with the form of the surface on which they rest; they are, on the whole, of a clayey type, but with gravelly intercalations. At Port Soldrick we have once more an example of the infilling of a pre-glacial recess, the drift being banked against cliff-like slopes of slate on both sides to a depth of 100 feet in the middle of the inlet, consisting, so far as can be seen, of till and gravelly bands containing shell-fragments. The Santon River, at present discharging through a rocky gorge at Cass-ny-Hawin 600 yards farther south, may have had its pre-glacial outlet at this place. A glaciated rock-surface is visible at the base of the drift at the southern entrance to Port Soldrick.

The clayey drift extends up to Cass-ny-Hawin, and also covers the rising ground inland to the south of that ravine; but where the Carboniferous Limestone sets in, the ground in the neighbourhood of the coast forms a lower undulating platform which is for the most part thinly covered with stratified gravel (pp. 470-2). This gravel is exposed here and there in the low cliff between Cass-ny-Hawin and Ronaldsway; at the latter locality traces of the Raised Beach are also present.

DERBY
HAVEN.

It is probable that in the inner part of Derby Haven, which is concealed by beach-stuff, the limestone may be overlain in places by boulder-clay, as this material is seen in the low bank at Ronaldsway, and masses of cemented drift-rubble cap the solid rock on the foreshore east of the farm-buildings. The Haven is surrounded by a rim of blown sand, resting for the most part on Raised Beach; and sand covers the isthmus running out to

FIG. 108. Section in drift-gravel in the cutting for the Marine Drive, between Port Soderick and Keristal.
Length, 50 yards; height, 15 to 25 feet.



- a Contorted sand loam and fine gravel; red loamy clay with stones in hollows 1 to 3 feet deep at top.
- b Sand and fine gravel.
- c Well-bedded fine gravel and sand, with a few subangular blocks of local grit; passing into coarser shingly gravel. Pebbles chiefly local, but with a few of extra-insular origin (flint, etc.).
- F Fault-like break, with contortions immediately to southward.

LANGNESS

Langness. Cumming states¹ that a cutting made for a drain in this isthmus showed "alternating layers of pebbles, sand and loam." The pebbles which occur throughout the blown sand on the *Racecourse* have probably been driven up in part by storm-waves and in part by the wind, entangled in rolling balls of sea-weed, both methods having been noticed in operation above high water mark in Castletown Bay. The blown sand rests on drift-gravel in the bank south of the causeway leading to St. Michael's Island; and pockets of similar gravel, occupying little hollows of the slate-rocks, are of common occurrence along the outer shores of Langness, but are all too small to map. On the western side of the promontory, however, where the Carboniferous rocks afford a less rugged surface, the gravel, partly of local and partly of foreign material, is sufficiently persistent to require mapping; a little boulder clay is also seen on this side, in the bank above the Raised Beach at Langness farmstead; and some large boulders, including Foxdale Granite, greenstone, coarse grit, etc., are conspicuous on the broad tidal-shelf of limestone. On this shelf the Raised Beach merges insensibly into the present shore.

Southern Coast; Castletown Bay to Calf Sound.

On the eastern shore of Castletown Bay the limestone-scars give place rather suddenly at *Sandwick* to a beach of sand and shingle which extends westward to the vicinity of the harbour. This beach is for the most part underlain by drift, as was proved by the exposure of patches of till in several places between high and low water during our survey of the coast.

The most easterly of these exposures was seen near low water within 20 or 30 yards of the disappearance of the limestone; another occupied a good breadth of foreshore opposite King William's College; and others occurred between half tide and low water at many points farther west up to within a few yards of the reappearance of the limestone. They were all of similar character, showing a hard stony till full of glaciated limestone-blocks, with a sprinkling of foreign pebbles and fragments of shells, among which a single perfect valve of *Leda pernula* was obtained.

HANGO
LL.

The only cliff-section of this drift is at *Hango Hill*, opposite King William's College, where the till rises for a short space to 30 feet above O.D., while the surrounding ground forms part of the gravel-platform (p. 471). This section was carefully studied and figured by Cumming,² whose description deserves quoting as an illustration of the remarkable insight of this observer at a time (1845-1848) when the phenomena of the glacial deposits were still imperfectly understood. It is as follows:—"We have a consolidated mass of black or dirty blue mud, such as we can easily imagine to be formed by the grinding down of the dark limestones and shales of this district, such a debris in fact as is formed in the yards of the stone-masons of this neighbourhood where this same limestone is cut and polished. In it we find mixed up confusedly gravel and sand, and pebbles (not large) of foreign rocks, granites, syenites and porphyries, fragments of the Coal-measures of Cumberland, and one or two chalk flints. We have some boulders of the insular granite and larger masses of insular rock, such as greenstone and old red conglomerate, but above all masses of limestone in rhomboidal blocks, some weighing upwards of a ton and having the appearance of transport from Coshnahawin, a mile and a half to the north-eastward. . . . These limestone blocks seem pushed over one upon the other, and piled up amongst the gravel, sand and clay in wondrous confusion."³ In another part of his book, Cumming shows that the changes in the appearance and colour of the boulder-clay depend upon the composition of the subjacent rock to the eastward, and adds:—"The analysis of Dr. Kemp (of St. Peter's College, Cambridge) for the purpose of determining

¹ "Isle of Man," p. 78.

² Quart. Journ. Geol. Soc., vol. ii. (1846), p. 338, and fig. in text; also "Isle of Man," pl. viii.

³ "Isle of Man" (1848), p. 69.

the percentage of lime in the marls of the north and south of the island, gave for a sample taken from Kirk Bride parish, near Point Craustal, only 5.145 per cent. of lime, whilst a sample from Hango Hill yielded about 24.5 per cent. A sample taken at Ronaldsway, a little to the westward of the basset edge of the old red sandstone, gave 6.75 per cent., and the same was very nearly the proportion of a mass from Strandhall.¹ He also discusses the erosion of the cliff at this point, and gives evidence to show that "in 1662 when William Dhone was here shot to death, the cliff was probably removed from 30 to 40 feet from the building"² (an old tower now nearly all carried away by the sea). Mr. Kendall has likewise described the section, and records, besides limestone, the following rocks in order of abundance:—"Vein-quartz, dark-red recrystallised sandstone, yellow sandstone, flints, diabase, Ailsa Craig eurite, clay slate. . . . The rarity of clay-slate is very remarkable."³

Between Hango Hill and Castletown Harbour a narrow strip of Raised Beach borders the shore, behind which rises a gravelly bank more or less covered with blown sand. South of the town there is no exposure of drift until we reach the quarry at Scarlet, where, under a covering of from 2 to 4 feet of clayey rubble-drift and till full of the local rock, occurs an excellently striated surface of limestone (p. 479). This was first described by Cumming, who distinguished three kinds of markings, "the deeper *polished groovings*, the *striations* or finer scratches *upon* the groovings, and the *indentations*"⁴; later descriptions have been given by several observers.⁵ A boulder of porphyritic greenstone, measuring 6 feet by 5 feet by 2½ feet, perhaps derived from the mass bordering the Oatland granite (p. 321), was uncovered in 1892 in the drift in this place. The entrance to the quarry has been cut through a patch of Raised Beach full of recent shells.

West of Scarlet Point, where the Carboniferous Volcanic rocks occupy the coast, drift is represented only by pockets of gravel in the hollows, until we reach the limestone at Poyll Vaaish, where it again thickens. The section in the "black-marble" quarry (p. 220) on the eastern side of this inlet has been described almost as frequently as that of the Scarlet quarry. It shows 6 to 10 feet of bouldery gravel-drift, clayey at the base, resting on a striated surface of limestone. The gravel contains many boulders of the local tuff and porphyrite, along with a few foreign stones. Patches of more clayey drift are seen beneath Raised Beach at a few points farther north, though gravelly material predominates at the surface a little way inland. In the low cliff west of Balladoole (Sh. 16) the drift, 8 to 10 feet thick, gravelly above and clayey below, is cemented into hard masses by calcareous percolation, as fully described by Cumming. (Op. cit., p. 137).

In the bend of the bay at this place, a gap 200 to 300 yards wide, in the limestone-scars on the foreshore opposite the mouth of the *Strandhall* brook, indicates the place where, when the sand and shingle of the beach is washed aside, peat with trunks of trees is revealed, as described in the preceding chapter (p. 413). The low cliff between *Strandhall* and Kentraugh is composed of till which descends in places to the foreshore and there covers striated surfaces of limestone (p. 479). It seems quite possible that the present tidal-flat of limestone in this bay, and in parts of Castletown Bay and Derby Haven, may nearly correspond to the tidal-flat of Preglacial times.

Where the slate-rocks are faulted in at Kentraugh, they rise in a hummock nearly through the drift, but sink again before reaching the mouth of the Colby River, opposite which, in 1892, stony till was visible in places on the foreshore. A little blown sand caps drift-gravel and till on the eastern side of the stream. Westward to Rhenwyllan the coast is fringed with a strip of Raised Beach, backed by a gravelly plateau. The foundations for

¹ Op. cit., pp. 113 and 365.

² Op. cit., p. 80.

³ Yn Lloar Manninagh, vol. i., p. 415.

⁴ Op. cit., p. 115.

⁵ J. Horne; J. Clifton Ward; W. Hewitt; P. F. Kendall. (See Bibliography for references.)

a protecting wall for the high-road along this strip, E. of *Mount Garne*, exhibited 12 feet of shingle, stained and cemented in places, resting on sandy clay without stones. Cumming was informed that in 1827 the sand which covers the broad tidal-flat opposite *Mount Garne* was swept aside by a storm and revealed the remains of an old forest, with traces of a primitive hut (p. 413-4). During the present survey the only exposure in this tract west of the mouth of the Colby was at half-tide about 200 yards east of the mill at *Rhenwyllan*, where patches of till and greenish glacial silt were seen.

17
MARY.

In *Chapel Bay*, the northern recess of Port St. Mary Bay, the glacial deposits occupy the whole cliff about 60 feet in height, the lower part composed of loamy till with small stones and crumbs of shells, passing up into stratified clay and loamy sand, with clean sand and gravel at the top. South of this there are no sections until we pass the harbour and reach the faulted outlier of Carboniferous Limestone forming *Port St. Mary Point*, which is overlain by a sheet of drift and beautifully glaciated, furnishing another of the localities repeatedly described in Manx glacial literature.¹ Mr. Hewitt has called attention to the manner in which the vertical as well as the horizontal surfaces of the limestone have been striated. He remarks, "... at the limekilns at Port St. Mary, the upper limestone beds end inland in a succession of six steps, against which abuts a mass of unstratified stony till. Each step is well polished and striated on both its horizontal and exposed vertical sides; the horizontal edges are well rounded off and the striæ may be seen running obliquely from the horizontal to the vertical faces. These steps have a total difference of height of from 5 to 6 feet."²

The section in the cliff 400 yards S.W. of the new breakwater is shown in the figure on next page.

Among the boulders on the foreshore at the time of my examination, derived from this drift, were one or two blocks of Foxdale granite; these were being hewn into shape preparatory to removal, and I was informed that similar blocks were at one time very abundant. Examples of this granite may be seen here and there all round the shores of Bay ny Carrickey; and a rounded boulder, measuring 3 feet by 2 feet by 1½ feet, which seems to be of Shap granite was seen near low-water mark in the middle of Perwick Bay (p. 338).

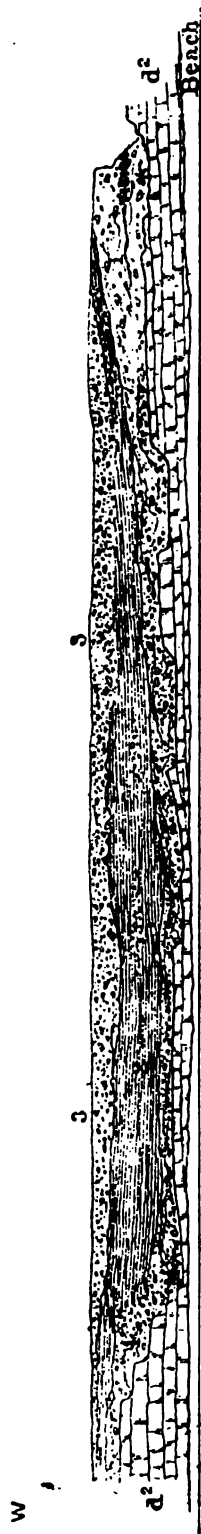
18
F.
ND.

West of the limestone-outlier the drift spreads more thinly over the rising slope of slate, but thickens again in an old hollow in Perwick Bay, and then fades to a mere sprinkling on the rugged coast beyond. Between Kioney Ghoggan and Calf Sound the only places where there is drift thick enough to map are in the recesses of Bay Stacka and *Baih ny Breechyn*, the first, E. and the second, W. of Spanish Head. A little gravel has lodged on the lower part of the slope at the extreme south-western corner of the Island; and a tiny patch of similar material, partly cemented, caps the islet of Kitterland in Calf Sound. If this tract had ever been submerged since Glacial times, these gravel patches must have been swept away by the tide-race through the Sound. Glacial striæ were observed abundantly on all the higher ground W. of Perwick, and by their direction mark the confluence in this quarter of the south-westerly flow of the leeside of the Island with the main south-south-easterly current of the ice sheet, some surfaces showing one direction and some the other, while a few have been successively scored by both streams.

¹ See Cumming, Horne, Kendall, Hewitt, op. cit. Cumming also discussed and figured the section in his paper "On the Superior limits of the Glacial Deposits of the Isle of Man." Quart. Journ. Geol. Soc., vol. x. (1854) p. 213.

² Proc. Liverpool Geol. Soc., vol. v. (1888) p. 356.

FIG. 109. Section in cliff west of old *Limestone*, Port St. Mary. Length, 100 yards; height, about 20 feet.



- 3 Gravel, with sandy and clayey seams; stones angular and subangular, and some boulders.
 - 2 Stratified clay, with stony seams and patches of gravel.
 - 1 Till with streaks of gravel, and subangular rubble; boulders chiefly limestone, but with some of distant origin; a few shell-fragments.
 - d² Flaggy Carboniferous Limestone.
- * Edges of limestone glaciated, with till banked against them.
 ** Edges of limestone shattered and overlain by rubble.

Interior of Southern Division.

N MEAY In entering Glen Meay from the west coast we pass at first through a
GLEN deep post-glacial ravine with craggy walls of slate (p. 148), but in the wider
HEN. valley above the bridge carrying the Dalby highroad we find banks of slaty
 till on both sides and a small alluvial flat in the bottom. Similar drift
 extends up the little tributary glen on the south, but dwindles and dis-
 appears from the main valley until we reach its sharp southerly bend and
 enter the part known as Glen Rushen. In the gully of *Glen Doo* (Sh. 12),
 a small tributary which falls into the main valley at the bend, there are
 several boulders of Foxdale Granite, and several more are seen in the bed
 of the main stream in this vicinity, whither they may have been carried by
 floods. The wet moorland sloping up east of Glen Rushen to South
 Barrule and northward to the rim of Foxdale is overspread by a fairly
 continuous sheet of rubbly local drift, with a base of hard slaty till in the
 hollows. This has been denuded away from the bottom of the main valley
 except around the head-waters W. of the mountain-road to Dalby, but is
 exposed in the gullies of the numerous small feeders. In one of these, on
 the S.W. side of the old Beckwith Mines, there is an interesting section
 showing grey till, 30 feet thick, banked against a little cliff of slate, pro-
 bably the wall of a buried preglacial ravine. In a lower part of the same
 gully we find 20 feet of grey clayey till with blocks of slate and quartz,
 overlain by 15 feet of gravelly till of similar derivation; and this may be
 taken as a typical section of the local hill-drift. As described in a previous
 chapter, boulders of Foxdale Granite are thinly sprinkled over the surface
 of the moorland as far north as the head of the streams descending into
 Foxdale from Kerroodhoo, and southward and south-westward to the
 summits of South Barrule and Cronk ny Arrey Lhaa. None were noticed
 on Dalby Mountain, west of Glen Rushen; the rounded summit of this
 hill carries a little slaty rubble with occasional foreign pebbles, too thin to
 map as drift; while its steep slopes, both east and west, are of bare slate.

LEY OF Crossing the well-glaciated ridge of South Barrule (See List of Stria,
TON RIV. p. 477), and passing around the head of Foxdale north of Granite Mountain,
 to the watershed of the Island, we reach the source of Santon River in a
 peaty hollow at 470 feet above O.D. Of this hollow, advantage has been
 taken for the construction of dams for the Foxdale Mines. To the north-
 eastward of it there lies the previously-described rising ground of *Archal-
 lagan*, with its train of foreign boulders. For nearly the whole of its
 length the Santon River flows southward in the middle of a broad drift-
 mantled depression with gentle slopes, differing greatly from the deep
 glens and ravines which characterize most of the Manx streams; and it is
 only at its mouth at Cass-ny-Hawin, where, as already mentioned (p. 462),
 the river seems to have lost its preglacial course, that it is bordered by
 craggy rock-walls. The drift which covers the depression is for the most
 part a clayey till, best seen in the eastern bank above and below Mullenar-
 agher (Sh. 13) and in the railway-cutting west of Santon Station; and is
 mainly composed of local detritus, but to the southward of Ballacorris con-
 tains a few foreign stones, probably brought over the watershed in the
 Archallagan train of extra-insular material. South of the Foxdale Granite
 outcrop, boulders of that rock are very numerous on the western slope of the
 valley; but on the eastern slope are of rare occurrence until we pass Balla-
 nicholas, south of which they are spread in limited numbers over the drift-
 covered ground eastward into the drainage basin of Glen Grenaugh. A
 single boulder of this granite was noticed still farther east, in the valley of
 a feeder of the *Crogga River* 600 yards due west of Southampton, under
 circumstances that did not suggest artificial transit though not actually dis-
 proving it. That the transport of this block may have been natural is
 rendered the less unlikely by the presence of boulders of the granite on
 the beach at Port Soderick at the mouth of the Crogga River, which like
 those in Port Grenaugh have probably been swept down from the upper
 reaches of the valley by flood waters at the melting of the ice.

The drift of the upper basins of the Grenaugh and Crogga River
 resembles that of the Santon valley, and needs no special description. Th

deep dry glen curiously excavated through a spur of slate-rock at Crogga, through which the railway passes, has already been mentioned (p. 170) as perhaps indicating a late-glacial flood-outlet from the upper part of the Santon basin when the mouth of that basin was still blocked by drift or by ice. The probable position of the pre-glacial channel of the Santon has also been pointed out in the coast-section (p. 462). The undulating plateau between Crogga Glen and Port Grenaugh, forming the interior of Santon Head, is more or less drift-mantled nearly up to the coast, as is well shown in the railway-cuttings. In the cutting 250 yards S.W. of Ballaquiggin (Sh. 17), a 5-ft. boulder of Foxdale Granite is seen embedded in till; but the most plentiful boulders in this tract are those derived from the adjacent outcrop of the Oatland Granite (p. 185), a well-marked train streaming off from this small boss southward and south-westward towards Seafeld and Ballavar.

The *Awin Ruy*, a stream joining the Silverburn at Ballasalla, has its source on the western side of Granite Mountain in a boggy col, corresponding to that of the Santon River on the eastern side; and maintains a course strictly parallel to that river even in its easterly curve. The ground intervening between them, about a mile in width, is comparatively low, and is for the most part drift-covered, though occasionally too thinly so to be shown on the map. The same drift-sheet, everywhere characterised by the abundance of Foxdale Granite boulders, extends westward under the above conditions into the drainage area of *Awin ny Reash*, and thence into the main basin of the Silverburn, reaching northward to the slopes of South Barrule and southward to the gravels and alluvium of the low ground near the coast. Cumming mentions¹ that close by the ~~Black Fort~~ at St. Marks there formerly stood a famous granite boulder, broken up however before he wrote, weighing between 20 and 30 tons, known by the name of Goddard-Crovan's stone, which was thrown, according to an old Manx legend, by the hero of that name from the top of South Barrule at his termagant wife who was rating him loudly at what she considered the safe distance of over two miles. A fine block of Foxdale Granite, broken by blasting, but originally measuring 10 feet by 7 feet by 6 feet, lies at the fork of *Awin ny Reash* at Moaney Mooar.

At Gildale near the head of *Awin Ruy* there is a small patch of sand and slaty gravel with a few foreign pebbles, including flint, red sandstone, etc.; and similar patches, though apparently with local pebbles only, occur on both sides of the Silverburn valley near Ballagilbert. Elsewhere the prevalent drift is firm slaty till where thick, and clayey rubble where thin, or the two in combination. In many places, on the flatter portions of the slopes of the broader parts of the valleys, the drift has a superficial covering of 'Colby Wash' (see p. 453), which in some cases apparently marks the site of small seasonal water-pools at the final stages of the glacial period. Among other localities, strips of this 'wash' occur towards the head of the Santon valley; to the W. of it between Shenvally and Ballavarvane;² in the *Awin Ruy* basin, N.W. of St. Marks; farther S., around *Cly-na-mona* (Sh. 12), $\frac{1}{2}$ mile S. of Ballamodha Mooar; towards the head of *Awin ny Reash*; and W. of the Silverburn, $\frac{1}{4}$ mile N. of Ballavarkish. The presence of a larger tract of similar material in the hollow at the foot of the hills, S.W. of Arbory, has been discussed in the preceding chapter (p. 413).

Half a mile below St. Marks the *Awin Ruy* is bordered on both sides for several hundred yards by curious hillocks and ridges of slate 20 to 30 feet high, due to accidents of erosion, the stream having lost its preglacial channel here and from time to time shifted its position in seeking the readiest passage across the flat barrier of rock. Such alterations of the stream-courses, of which we have previously noticed many instances in the

¹ "Isle of Man," p. 171

² Spelt Ballavarane, on one-inch map.

SILVERBURN
BASIN.

Manx valleys, are characteristic of drainage-waters subject to great seasonal fluctuations. In the Isle of Man they may be assigned to the period when the surface-flow was stopped by frost during the winter, but became very copious during the melting of the snow in the spring and early summer. Another peculiar effect of post-glacial erosion is exemplified at the head of the Silverburn basin, where pre-glacial ravines filled in with drift have been re-excavated with double channels, either by twin streams or by a single stream alternately attacking the slopes on the opposite sides of the valley and sinking down into the drift on both sides of the buried rock-channel, leaving a narrow interrupted ridge of drift to separate the twin gulleys. These conditions are found near the head of the main stream in the drift-filled col between South Barrule and Cronk Fedjag; and slightly differently at the head of Glion Cam, a mile farther east. In both places erosion is now at a standstill and the banks and bottoms of the valleys overgrown with vegetation. This peculiarity is repeated in various stages of development in other parts of the Island. It exists on a more extensive scale in the re-excavated drift-filled valleys of north-east Yorkshire, as described some years ago by my colleague Mr. G. Barrow.¹

Around the head of the Silverburn and its tributaries the upward limit of the drift deposits is ill-defined, the boulder-clay fading off on the higher slopes into thin sheets and hillocks of sub-angular bouldery rubble, with only a few scratched stones. Striated rock-surfaces are fairly numerous on the surrounding watershed. In the lower part of the valley there are several good exposures of slaty till in the river-banks, especially between Ballacannell and Grenaby. One of these, south of Grenaby Farm, has been described and figured by Mr. Horne;² it shows, at the base, 30 ft. of hard grey till with insular stones, including Foxdale Granite; overlain by 1 to 2 ft. of stratified silt and fine gravel, with a capping of stony clay. Farther south, where it extends over the Carboniferous rocks, the drift becomes redder from the intermingled detritus of the Basement Conglomerate, changing afterwards to dark bluish-grey as the débris of the dark shaly limestone attains prominence. These local changes in the colour of the boulder-clay were admirably described and interpreted by Cumming in 1845.³

COLBY
RIVER.

The drift around the sources of the Colby and its branches resembles in all points that of the Silverburn valley and needs no special description. One exposure however deserves passing notice, as showing how a deceptive appearance of subaerial weathering may be produced on a surface between two masses of till. The section in question occurs in a side-gully which joins the Colby River on the E. just below the waterworks reservoir near its source. It reveals 20 feet of slaty till, blue above and below, but with a narrow band of red decomposed earthy material in the middle of the section. When traced up the gully, this red band is found to spring from a decomposed ochreous seam in the solid slates, possibly one of the crushed schistose diabase-dykes so numerous in these rocks (p. 306). Hence the decomposition is pre-glacial, although the weathered material has been streaked out into the mass of unweathered till. Weathered surfaces between two boulder-clays are sometimes adduced as sufficient evidence for an inter-glacial period, and it is therefore advisable to point out a case of this kind in which such a conclusion would be erroneous.

Low-level Drifts of the Southern Basin.

The strip of ground between the coast and the main-road from Ballasalla to Port St. Mary forms a low-lying tract in which many of the features of the drift-plain of the North are reproduced on a smaller scale.

¹ Mem. Geol. Survey; North Cleveland, p. 69.

² Op. cit., pp. 19-20.

³ Quart. Journ. Geol. Soc., vol. ii., p. 339.

As in the latter tract, we find gently sloping platforms of gravel spreading out around the mouths of the principal streams, and enclosing alluvial hollows which have formed shallow lakelets or flood-basins until drained by artificial means. It seems probable that, like the Northern Curragh, the whole of this area has been occupied by a fresh-water lake during the closing stages of the Glacial period, held in on the south either by the receding ice-sheet or by higher drift-ground since removed by the sea. It differs however from the northern tract by including a few small islands of solid rock which rise above the superficial deposits, and by the more gentle slope of the drift-covered hills bounding it to the northward.

The most easterly portion of the gravel-platform extends from the coast north of Derbysaven up to the Silverburn S. of Ballasalla, falling gently southward, from 70 to 80 feet above O.D. between Creggans and Ballahick to 30 to 40 feet near the coast. It is interrupted by the shallow stream-channel descending from a small flood-basin near Ballahick, and by the clayey mound of Creggans Hill. Cumming believed this hill and the similar rise known as *Skybright Hill* (Sh. 16) near St. Lupus (Malew) Church to be composed entirely of drift,¹ in which case they might be described as 'drumlins;' but in both places there is evidence tending to show that the knolls have a solid core of limestone, upon which boulder-clay is moulded. In a small excavation adjoining the railway, on the western side of Creggans Hill, a striated floor of limestone is revealed, underlying till. The Silverburn flows through a shallow depression in the gravel-flat, which is margined in places by slight terraces probably dating back to early Post-glacial times. Cumming notices the discovery of elk-remains in one of these, as previously mentioned (p. 386).

West of the Silverburn the platform extends up to an alluvial hollow S. of Billown Moor (p. 412), but in places there seems scarcely sufficient gravel upon it to cover the subjacent boulder-clay. An excellent section is exposed in it by the railway-cutting W. of Castletown, which reveals at the western end strongly current-bedded gravel 10 to 20 feet thick, resting farther E. on contorted clayey sand with a few pebbles and blocks of limestone, some scratched, up to 1 foot in diameter. This sand rises higher in the section eastward, and appears to pass into tough till with large glaciated boulders of limestone; but, in 1892, this part of the cutting was grassy and obscure. The gravel consists largely of limestone, both rounded and subangular; with some grit, greenstone, quartz, etc. from the Manx slates; and flint, porphyrite, etc. foreign to the Island. It also contains a few small shell-fragments, and some of the limestone-blocks show *Pholas* and *Cliona*-borings. From its composition and relation to the boulder-clay, this portion of the gravel is clearly of glacial origin, and not merely a delta of flood-gravel washed down by the Silverburn.

We were informed that a well at the hotel at Castletown Station was sunk through the drifts for 45 feet, and obtained an artesian flow at that depth, below boulder-clay, from a shingly bed resting on the top of the limestone.

West of the above-mentioned alluvial hollow the limestone, enwrapped by till, rises into the hummocky ridge of Cronkdarragh and Balladoole. A lenticular mound of limestone-gravel, known as *Cross Welkin Hill*, probably resting for the most part on bare limestone, forms the summit of the ridge at about 90 feet above O.D.

The difficulty in respect to the composition of the low-lying and partly alluvial tract south of Arbory (otherwise known as *Ballabeg*) and Colby has been discussed in the preceding chapter (p. 413). That the northern slopes of this low ground are deeply mantled with boulder-clay is shown by the railway-cuttings west of *Ballabeg* Station; and that similar material probably covers most of the rising ground on its southern margin is indicated by the character of the cliff-sections between *Strandhall* and *Kentraugh*. A well at the school at Arbory, 44 feet deep, is reported to have passed through boulder-clay into slate-rubble ("rotten callis"). Moundy patches of coarse slaty gravel border both sides of the tongue of alluvium at Arbory; and a similar patch occurs a little to the east of

LOW
GROUND
AROUND
CASTLE-
TOWN.

ARBORY
AND COLBY

¹ "Isle of Man," pp. 52-54.

Colby, where it forms definite banks at the margin of the hollow; while at the mouth of Colby Glen there is a spread of gravel which is probably a late-glacial flood-delta.

West of the Colby depression we again find a nearly level tract of drift-gravel between the hills and the south coast, usually at an elevation of from 60 to 80 feet above sea-level. This platform extends from Colby to Port St. Mary, and thence through the broad depression between the slate hills to Port Erin, while an arm runs up northward past Trinity Church towards the head of the Fleshwick gap (p. 461). It has previously been mentioned that the gravel may possibly represent a 'kame-delta' spread out by waters draining from the ice through this gap (p. 371). The patches of alluvium which break its surface need no further description than that already given (pp. 412-5). The slopes rising from the platform are for the most part thinly overspread with boulder-clay, with bare slate-rock cropping out on their upper portion.

LL HILL. The little detached tract of hilly ground lying to the south of the gravel flat, and forming the south-western extremity of the island, has a few limited patches of slaty drift in its hollows and glacial striæ in places on its summits (p. 479), but with no features calling for further remark.

The Calf of Man.

The drift-deposits of The Calf are practically limited to a few patches of clayey and gravelly rubble in hollows of the slate, with a single gravel-mound in an exposed position at about 300 feet above O.D. on its north-eastern slope. The presence elsewhere of a sprinkling of drift-stones, including Foxdale Granite and a few extra-insular rocks; and of smoothed rock-surfaces occasionally showing scratches directed towards S.S.E.; complete the proof of its glaciation. The drift touches the coast only in the recess of *Rarick* (Sh. 18) at The Puddle, where 10 to 20 feet of clayey gravel and till are exposed, and at the heads of gullies at *Ghaw Lang* and *Gibbdale Bay* where there is a little till. The largest patch of drift underlies the enclosed and cultivated land in the depression south of the farmstead. The isolated gravel-mound mentioned above, into which a small pit has been opened, lies 650 yards E.N.E. of the farm buildings. In his paper "On the Geology of the Calf of Man,"¹ Cumming made especial reference to this gravel and figured a section across it. As it was much better exposed at that time than now, the following passages are quoted from his description:—"The mass itself (which is about 13 feet thick and 50 feet across in each direction) consists of boulders, gravel and sand. The sand is chiefly at the base of the formation, and in it occur a few pebbles and laminae of fine gravel. As we ascend, the size of the fragments of rock increases; we have a bed of fine, then of coarse gravel, and the uppermost portion consists generally of large rounded pebbles with good-sized boulders which are scratched and grooved. Most if not all the rocks are foreign. There are not any which the author can certainly claim as belonging to this locality." There are red and grey syenites, porphyries, granites, grit and sandstone, either from Cumberland or the south of Scotland. And though there is no doubt that the drifting currents of this period passed over the limestone area of the south of the island in this direction, the author has not met with a single pebble of limestone in this mass of boulders and gravel. . . . It will be observed that the stratification or quasi-stratification is not horizontal; it seems, in fact, to follow in general the outline of the surface of the hillock itself, and to consist of concentric layers forming a semi-ellipsoidal mass."

¹ Quart. Journ. Geol. Soc., vol. iii. (1847), pp. 179-185.

² This passage probably refers to the lower portion of the gravel; at any rate, in the uppermost part to a depth of 4 to 6 feet, which was all that was exposed at the time of the present survey in 1892, subangular fragments of slate constituted the larger proportion of the deposit.

LIST OF SHELLS FROM THE GLACIAL DEPOSITS OF THE ISLE OF MAN.

Reproduced with some additions and alterations from Mr. P. F. Kendall's list in "Yn Lioar Manninagh," vol. i., No. 12 (Oct. 1894), pp. 416-418.

Note.—Mr. Kendall's specimens were obtained chiefly from the cliffs of the east coast north of Ramsey and of the west coast north of Peel; his tables state the local distribution under the following headings:—Boulder Clay, Lower Mooragh (North Ramsey); Mooragh Sand; Boulder Clay, Upper Mooragh; Shellag (Point Cranstal) Sand; Shellag Clay; Glen Wyllin; and Cliffs north of Peel. The relationship to the existing fauna is also shown in columns marked "Northern," "Recent British," "Southern," and "Extinct." It has not been thought necessary to reproduce these particulars in the present list, but the locality is stated where an addition is made to Mr. Kendall's list. The following species given by Mr. Kendall on the authority of Cumming and Forbes, and apparently not since verified have been omitted, as most may be only synonyms:—*Cardium lævigatum*, L., *Astarte danmoniensis*, Lamk.; *A. pisiformis*, S. V. Wood; *Venus gallina*, L.; *Buccinum ciliatum*, Fabr.; *Fusus Sabini*, Gray; *Balanus communis*, Pult.; *B. uddevallensis*, L.

The species in italics are our additions to the list. The prefixed asterisk indicates that the determination has been verified in the palæontological department of the Survey, either from specimens obtained during the survey, or from the large collection placed at our service by Rev. S. N. Harrison, of Ramsey, to whom our best thanks are due for the loan and gift of specimens. The species from Mr. Harrison's collection are denoted by the letters S. N. H.

[*POSTSCRIPT.*—While this memoir was in the press, a list of the Foraminifera of the glacial clay at Shellag (Cranstal) has been published by Mr. Joseph Wright, in which 72 species are recorded. See *Yn Lioar Manninagh*, vol. iii. (1902) pp. 627-629.]

CIRRIPEDIA.

**Balanus crenatus*, Brug. From shelly drift at depth of 228 to 240 feet in No. 6 boring, Point of Ayre, see p. 342.

**Balanus Hameri*, Ascan. From shelly drift at depth of 228 to 240 feet in No. 6 boring, Point of Ayre, see p. 342.

Balanus porcatus, *Da Costa*

POLYZOA.

Eschara, sp.

Lepralia, sp.

BRACHIOPODA.

**Rhynchonella psittacea*, Chemn. From shelly drift at depth of 228 to 240 feet in No. 6 boring, Point of Ayre, see p. 342.

LAMELLIBRANCHIATA.

**Anomia ephippium*, L.

Arca lactea, L.

Artemis exoleta, L.

**Astarte borealis*, Chemn. (Fig. 80, p. 336).

* — *compressa*, Mont.

* — *sulcata* var. *elliptica*, Brown

- Astarte sp. ("a small species with concentric growth and a rounded form, very like the sub-globular *Woodia*, but not agreeing with *W. digitata* P. F. K.).
- Cardium echinatum*, L.
 ——— *edule*, L.
 * ——— *grœnlandicum*, Chemn. Point Cranstal, S.
 ——— *norvegicum*, Speng.
 * *Corbula gibba*, *Olivi*
 * *Cyprina islandica*, L.
Donax, sp.
Glycimeris (*Panopæa*) *norvegica*, Speng.
Lutraria, sp.
 * *Mactra solida*, L.
 ——— *subtruncata*, DaCosta
 * *Modiolus modiolus*? L. Point Cranstal. S. N. H.
Mya arenaria, L.
 ——— *truncata*, L.
 ——— var. *uddevallensis*, Smith
 * *Mytilus edulis*, L.
Nucula nucleus, L.
Nuculana (*Yoldia*) *pygmæa*, *Münst.* ("in Forbes's list as *Leda pygmæa*, Goldf." P.F.K.).
 ——— (*Arca*) *minuta* var. *tumida*, H. P. C. ("in Forbes's list as *Leda minuta* P.F.K.).
 ——— ——— *pernula*, O. F. Müller ("in Forbes's list as *Leda rostrata*, Lamk." P.F.K.).
 * *Ostrea edulis*, L.
 * *Pecten maximus*, L.
 ——— *opercularis*, L.
 * *Pectunculus* (*Axinea*) *glycimeris*, L.
Pholas crispata, L.
 * *Psammobia ferröensis*. Chemn. Point Cranstal, S.
Saxicava arctica, L.
 * ——— *rugosa*, L.
 * *Tapes*, sp. Point Cranstal, S. N. H. (Kendall nomen *Tapes decussatus*, L., but on authority of Cumming).
 * *Tellina balthica*, L.
 ——— *calcareæ*, Chemn.
Venus casina, L.

SCAPHOPODA.

- Dentalium abyssorum*, Sars
 * ——— *entalis*, L.

GASTEROPODA.

- Acmaea* (*Patella*) *virginea*, L.
 * *Admete viridula*, Fabr.
Aporrhais (*Chenopus*) *pes-pellicani*, L.
 * *Buccinum undatum*, L.

- **Buccinum undatum* var. *tenerum*, Sow. Point Cranstal, S. N. H.
Bulla? ("fragmentary shell belonging to the Bullidæ." P.F.K.).
- **Columbella sulcata*, Sow.
—— (Mitrella) sp.
- **Cypræa* (*Trivia*) *europæa*, Mont.
- **Fusus* Forbesi, Strickl. (Fig. 84, p. 336).
- * — cf. *longiroster*, Brocchi (Fig. 85, p. 336). Point Cranstal, S. N. H.
- **Lacuna divaricata*, Fabr.
Littorina litorea, L.
—— *obtusata*, L.
- **Murex erinaceus*, L.
- * — *tortuosus*, Sow. Point Cranstal, S. N. H.
- **Nassa incrassata*, Müll.
- * — *Kermodei*, P. F. Kendall (Fig. 83, p. 336).
- * — *monensis*, Forbes (Fig. 82, p. 336).
- *reticulata*, L.
- * — *serrata*, Brocchi (" = *N. reticosa*, Sow = *N. pliocena*, Strickl." P. F. K.). (Fig. 81, p. 336).
- **Natica Alderi*, Forbes
- * — *clausa*, Brod. and Sow.
- * — *grænlandica*, Beck
- *monilifera*, Lamk.
- **Patella vulgata*, L.
Pleurotoma lævigata, Phil.
—— *pyramidalis*, Ström.
—— *turricula*, Brocchi
- Puncturella* (*Cemoria*) *noachina*, L.
- **Purpura lapillus*, L.
Rissoa, sp.
- **Trichotropis borealis*, Brod. and Sow.
Trochus, sp.
- **Trophon antiquus*, L.
—— var. *contrarius*, Gmel.
- * — *bamffius*, Don. From No. 6 boring at Point of Ayre, at depth of 228 to 240 feet; and in S. N. H.'s coll., from Point Cranstal.
- * — *clathratus*, L. (Fig. 86, p. 336).
- * — var. *Gunneri*, Lovén. Point Cranstal, S. N. H.
- * — (*Fusus*) *Fabrici*, Beck (= *T. craticulatus*, Fabr.). (Fig. 87, p. 336). Point Cranstal, S. N. H.
- * — *gracilis*, DaCosta
- * — *muricatus*, Montagu Point Cranstal, S. N. H.
- * — *propinquus*, Ald. Point Cranstal, S. N. H.
- * — *sp. nov.* Point Cranstal, S. N. H.
- **Turritella terebra*, L.
- **Voluta-mitra grænlandica*, Beck (= *Mitra*, sp. P.F.K.). Point Cranstal, S. N. H.

LIST OF GLACIALLY-STRIATED ROCK-SURFACES OBSERVED IN
THE ISLE OF MAN.

The place-names in italics are those appearing only on the six inch and not on the one-inch map of the Ordnance Survey. The list is arranged in the order of the six-inch maps, except in two or three cases where a group of striæ would be dispersed by strict adherence to this rule.

Number of six-inch Ordnance Map.	Locality.	Rock-surface.	Direction of Principal Striæ.	Remarks.
Sheet 5	550yds. * E. of Park Moor near Ramsey - - -	quartz-vein	N. 20° E	faint.
"	Slieau Lewaigne 400yds. W. of Lewaigne Cottage	sheared grit	E. 30° S.	
"	Road 200yds. S.W. of Ballacreggan - - -	slate	S. 30° W.	perhaps on block
"	Maughold Head, 480yds. N. of Church - - -	sandy slate	S. 10° E.	
"	do. 350yds. E.N.E. of Church - - -	"	S.	
Sheet 6	Cliff at small headland N. of Ballanayre Strand -	slaty flags	E. 10° N.	? glacial.
Sheet 7	Glen N. of Slieau Dhoo, 450yds. S.S.E. of Glendhoo Farm	striped slate	E. 30° S.	? glacial.
"	Creg Betn on N. slope of Slieau Monagh - - -	quartz-vein	S. 20° E.	see p. 361 a and 100.
"	Snaefell; tramline 40yds. from Summit Station	slate	S. 10° E.	altitude as the high in the l p. 361.
"	do. N. slope; tramline, N. 10° E. of summit	"	S. 25° E.	
"	Snaefell; N. slope; tramline, N. 55° E. of summit	"	S. 45° E.	
"	Snaefell; W. slope; tramline, S.W. of summit	"	E. 25° S.	altitudes 1,400ft. as
"	do. W. slope; tramline, S.S.W. of summit	"	S. 15° E.	
Sheet 8	Snaefell; N.E. spur; 350yds. E. of Ramsey road	quartz-vein	S. 10° E.	faint.
Sheet 7	Mullagh Ouyr; near summit, 70yds. S.W. of wall across mountain	"	S. 15° W.	
"	Mullagh Ouyr; near summit, 150yds. S.W. of wall across mountain	"	S. 5° W.	altitudes 1,500ft.
"	Mullagh Ouyr; near summit, 170yds. S.W. of wall across mountain	"	S. 15° W.	
Sheet 8	Col N. of Clagh Ouyr, 20yds. S.W. of wall across mountain	"	S. 30° E.	
"	Same ridge; 550yds. N.E. of wall across mountain	"	S. 35° E.	obscure.
"	S.E. side of ridge, 550yds. N.W. of Park Lewellyn	slate	E. 30°-35° S., crossing others	also on face, see
"	do. 150yds. N.E. of last - - -	"	S. 30° E.	
"	Ballasalg, in road leading to School - - -	"	S. 35° E.	
"	do. 500yds. E.N.E. of Magher-e-breck -	"	S. 30° E.	also faint
"	Ballagorra; roadside 400yds. N.N.W. of hamlet -	gritty flags	S. 30° E.	ings (of good. others ob 300yds. S.S.E.
"	Cliff, S. side of Gob ny Garvain - - -	"	W. 10° S., crossing others	below see p.
"	Near old cottage, 350yds. S.E. of Trinity Church-	flaggy slate	S. 10° E.	? glacial.
"	Laxey Valley; N. slope 450yds. N.E. of Laggan Agneash	quartz-veined grit	S., also S.E. S. 40° E.	
"	Laxey Valley; S. slope; tramline S.S.W. of Laggan Agneash	"	E. 35° S.	
"	Laxey Valley; S. slope; tramline half mile E.S.E. of last	gritty flags	S.E.	faint.
"	Cronk y Vaare; summit - - -	quartz-vein	S. 40° E.	
"	do. 130yds. E. of last - - -	"	E. 35° S.	good exam
"	do. 140yds. E.N.E. of last - - -	"	E. 30° S.	ated (
"	S. corner of coppice 800yds. N.W. of Baljeau -	"	S. 25° E. and S. 40° E.	faint. two dire
Sheet 11	Crag in field 700yds. W. of Baljeau - - -	quartz-veined grit	S. 10° E.	
Sheet 8	Slieau Ruy; 450yds. N.E. of summit - - -	quartz-vein in granite	S.E.	obscure; tude

* The distances have been measured on the 6-inch field maps.

Locality.	Rock-surface.	Direction of Principal Striæ.	Remarks.
St. Patrick's Isle ; N. shore, outside castle wall -	flags	S. 10°-20° W.	? glacial.
do. do. east side of prison -	"	S. 30° W.	
Peel Hill, 170yds. S.S.W. of Corrin's Tower -	"	S. 15° W.	
do. 450yds. S.S.W. of do. -	"	S.W.	also more faintly in other directions.
Contrary Head ; cliff-top on N. side -	"	S. 40° W.	
Small quarry 100yds. inland, 300yds. S. of Trale Cabbage	"	W. 35°-40° S.	also on vertical side of boars.
Small quarry east side of stream 150yds. N.E. of Staarvey	grit	E 10° N.	
Field, 230yds. S.E. of Lambell Moor -	slate	S. 20° E.	
East slope of Neb Valley ; old quarry N.E. of ruined brick-kilns near Beary	"	S. 15° E.	faint ; ? glacial.
Low crag 230yds. E. of last -	"	S. 10° E. also S.E. and others	intercrossing striæ.
do. 40yds. E. of last -	"	S. 10° E.	also on vertical side of crag.
Sileau Whuallian ; near crest, 170yds. S.W. of wall across mountain	"	S. 45° E. and others crossing	good.
Sileau Whuallian ; near crest, 180yds. S.W. of last	"	S. 30° E.	altitudes about 1,000ft.
Sileau Whuallian, 280yds. S.W. of The Cairn	quartz-vein	E. 25° S.	faint.
Prolongation of Sileau Whuallian ridge ; 150yds. N.W. of Carnagray	"	E. 25° S.	good.
Prolongation of Sileau Whuallian ridge ; 300yds. S.W. of last	slate	E. 35° S.	"
Archallagan plantation ; gutter 200yds. S.E. of Cornelly Mines	"	S. 35° E.	see p. 351.
Small quarry near edge of moor 100yds. E. of Ballashimmin enclosure	flaggy slate	E. 30° S., crossing E. 20° N.	altitude about 1,350ft.
Crag S. of Colden River, 800yds. W. of confluence with E. Glass	slate	S. 15° E.	
do. 50yds. E. of last -	"	S. 25° E.	
do. 450yds. S. of last -	quartz-vein	S. 10° E.	altitude about 1,350ft.
Old slate quarry at The Crag, S. of Colden mtn.	slate	S.	
Carn Gerjoll, 500yds. S.W.W. of Cairn -	quartz-veined grit	S. 10° W.	
Sileau Ree ; 500yds. N.E. of ordnance station -	quartz-vein	S. 20°-30° E.	above 1,000ft
do. 30yds. E. of do. -	"	S. 30° E. and fainter S. 5° E.	
do. 30yds. S.W. of last -	quartz-veined grit	S. 35° E.	
do. 200yds. S. 10° E. of ordnance station	"	S. 20°-30° E.	altitude 1,268ft.
Greeba Mtn. ; 450yds. E. of summit -	slate	S. 30° E. and fainter S. 25° W.	
Gob ny Creg on Creg ny Greeba -	"	E. 5°-15° N.	
Slope E. of Baldwin Riv., 650yds. N. 10° E. of Balliargey	flaggy slate	S. 5° E.	400ft.
300yds. S. of Gretchveg near Laxey -	flags	S. 10° E.	? glacial
Rough ground 90yds. W. of highroad W. of Laxey Pier	"	E. 40° S.	faint.
Tramline 350yds. N. of Seaview, near Laxey -	"	S.	faint.
do. W.S.W. of Baldroma Moor -	gritty flags	S. 25° W.	
Clay Head ; cliff, 300yds. S. of Braggan Point -	flags	S. 5° E.	
do. do. 600yds. S. of do. -	"	S. 20° W.	good ; ascending slope.
do. do. opposite "The Clytt" -	"	S. 15° W.	
Barrule Beg (N. spur of Bont Barrule), 600yds. N.E. of Slate Quarry	quartz-vein	E. 40° S.	also W. 5° S. on east side of rock.
Barrule Beg 300yds. N.E. of Slate Quarry -	slate	S. 30° E.	also faint, W. 25° S.
Barrule Beg, west slope, at small slate trial, 250yds. N.W. of Quarries	"	E. 25° S.	all above 1,000ft. in altitude.
North-west slope of South Barrule, 640yds. N. of summit	quartz-vein	W. 35° S.	
North-west slope of South Barrule ; W. of Coaglin ny Cregun	"	W. 35° S.	
West slope of South Barrule ; 30yds. W. of Creg ny Vaare	slate	S. 5° E.	ade Mr. P. F. Kendall. *
North slope of Granite Mtn., Foxdale ; 880yds. E. of Castletown highroad	quartz-vein in granite	S. 20° E.	on or near main watershed of inland ; altitude about 650ft.
South-east slope of Granite Mtn., Foxdale ; 750yds. W. of Renshent	"	S. 20°-30° E.	
South-east slope of Granite Mtn., Foxdale ; 50yds. S. of last	"	"	
Moor S.E. of Cronk Fedjag ; 600yds. S. of mtn.-road	striped slate	S. 30° E.	good ; altitude about 1,100ft.

* *Yn Lloar Ma ningsh*, vol. I., No. 12 (1884), p. 406.

Number of sheets Ordinance Map.	Locality.	Rock-surface.	Direction of Principal Stria.	Re
Sheet 12	Moor S.E. of Crank Padjeg; small quarry 750yds. S. of main road	striped slate	S.	
"	Near St. Mark's; small quarry in field 600yds. S.E. of church	flaggy slate	S. 10° E.	good.
Sheet 13	Slican Churn; 600yds. E. of Ballacallan Moor - Adjoining outbuildings of new house, 300yds. S.W. of Ballacallan	quartz-vein flags	S. 15° W. S.E.; also S. 40° W.	rock? in; faint.
"	Small quarry at N.W. side of Santon granite, N. of road	baked flags	S. 30°-50° W.	good.
"	Douglas: slope S. of Harbour, on roadside behind St. Anne's Hotel	flags	S. 30° W.	
"	Douglas Head; slope S. of outer pier	"	S. 15°-30° W. and others	
"	do. near top of slope, above road	"	S.W.	
"	do. tramline opposite Puddler's Green	"	S. 30° W.	
"	do. 100yds. W.A.W. of last	"	S. 30° W.	
"	do. 100yds. E. of Pigeon Stream	"	S. 25° W.	
"	Tramline 250yds. E. of Port Wallberry	"	S. 25°-35° E. W. 25° S.	altitude of faint; 7 ft
"	Cliff-top at Wallberry Hill	"	W. 40° S.	
"	Ridge (Curwen) 500 yds. S.E. of Numbury Howe	quartz-vein flags	S. 30° W.; also S. 30° E.	
Sheet 14	Cliff 250yds. N.E. of Port Groulle	"	S. 30° W.	
"	West side of Banks Howe, S. of Groulle Tram Station	"	S. 5° W.	
"	North slope of Banks Howe, E.S.E. of Groulle Tram Station	"	S. 30° W.	
"	North slope of Banks Howe, 150yds. S.E. of last	"	S. 30° W.; also W. 20° S.	
"	North-east slope of Banks Howe, by side of tramline	"	S.W.	
"	North-east slope of Banks Howe, by side of tramline, 50yds. S. of last	"	E.; also E.S.E.	
"	North-east slope of Banks Howe, by side of tramline, 70yds. S. of last	"	S.S.W.	also on v inclined wards
"	North-east slope of Banks Howe, crag below tramline	"	S. 40° W. S. 5° E. and others	
"	South slope of Banks Howe, by side of tramline	"	S. 5° W.	
"	South slope of Banks Howe, by side of tramline, 50yds. W. of last	"	S. 5° W.	
"	New road at Howetake, 150yds. N. of Onchan Harbour	"	"	
Sheet 15	Cliff at deep gully, east side of Fleahwick	slate	E. 15° S.	
"	Bradda Hill, east side; 300yds. W. of Ballaltonney	"	S. 10° E.	also on v inclined (see p. 3)
"	Bradda Hill, 350yds. inland, E. of North Bradda Mines	"	S. 30° E.	
"	Bradda Head, north side; cliff opposite Carn I'oid	grit	S. 15° E.	
"	Bradda Head, south side; above cliff; 100yds. E.N.E. of South Bradda Mines	slate	E. 20° S., cross- ing S. 20° E.	
"	Bradda Head, south side; above cliff; 400yds. E.N.E. of last	"	S. 20° E.	
"	South of Port Erin; cliff 450yds. S. of Kione-ny-Gares	"	W. 10° S.	
"	Crest of slope above cliff, 500yds. S.S.W. of Bay Fine	"	S. 15° E.	
"	Crest of slope above cliff, 70yds. S.E. of last	"	S. 15° E.	
"	Top of cliff, 200yds. S.W. of last	"	S.	
"	do. in recess at Aldrick, and again 50yds. inland	"	S. 40° W. (chief), also W. 10° S.; S. 30° E. and others.	several inter-
"	In recess at Aldrick, 150yds. inland, S.E. of last	"	S. 15° E. and others.	
"	Top of small headland S. of Aldrick	"	S. 2° W.	
"	Mull Hill, N. side, 80yds. E. of road at Howe	grit	S. 10° W.	obscure.
"	do. top, 20yds. N.W. of stone circle	quartz-vein in grit slate	S. 10° E.	
"	Cregnelsh, at N. side of road in hamlet	"	S. 10° E.	
"	do. 200yds. S. of hamlet, on road to Chasms	"	S. 20° E.	
"	Cregnelsh, rough ground 500yds. E. of hamlet	"	S.	obscure: 11
Sheet 16	Lhattee-ny-Beinn, N. of Fleahwick, 200yds. S.E. of Gob Beinn	quartz-vein	S. 30° E.	
"	Lhattee-ny-Beinn, N. of Fleahwick, 250yds. S.S.W. of Gob Beinn	"	S. 20° W.	obscure.

Locality.	Rock-surface.	Direction of Principal Striae.	Remarks.
<i>Slea ny Beinne</i> N. of <i>Fleashwick</i> , 380yds. W. of <i>kill</i>	quartz-vein in microgranite dyke grit	S. 20° E.	
round E. of <i>Carnanes</i> , 430yds. S.S.E. of <i>ll</i>	"	S. 30° E.	
round E. of <i>Carnanes</i> , 300yds., S.S.W. of <i>rock</i>	"	S. 40° E.	
round E. of <i>Carnanes</i> , 400yds. S.W. of last	"	W. 40° S.	
arry 400yds. W. of <i>Scholaby</i> - - -	striped slate	S. 5° E. and fainter S. 50° E.	good.
350yds S. of <i>Ballacorkish</i> South	"	S. 25° E., crossing S. 10° W.	
250yds. S.S.E. of <i>Ballagawne</i> , <i>Arbory</i> -	"	W. 15° S.	
quarry 180yds. S.W. of <i>Ballavarkish</i> , <i>ry</i>	"	S. 25° E., crossing stronger set, S.W.	good.
<i>Mary Point</i> , low cliff at S. side of break-	Carb. Limestone	W. 26° S.	
<i>Mary Point</i> , low cliff opposite <i>Carrick</i>	"	W. 20° S.	see p. 466.
<i>Mary Point</i> , low cliff 70yds. W. of last	"	S. 30° W.	
re E. of <i>Kentraugh</i> , 25yds. from sea-wall, to boundary fault	"	W. 20° S.	see p. 445.
marble " quarry, S. side of <i>Poyll Vaalish</i> and adjacent cliff at <i>Scarlet</i> , W. side of <i>etown Bay</i>	" (upper)	S. 50° W.	
quarry adjoining railway opposite <i>Creg-</i>	"	W. 20° S.	see p. 463.
1 mile N.N.E. of <i>Castletown Station</i>	"	S. 5° E., crossing others S. 40° W.	
arry, 270yds. E.N.E. of <i>Santon Church</i> -	slaty flags	S. 20° W.	
l. edge of <i>Port Soldrick</i> , <i>Santon</i> - -	flags	W. 5° S. and others	under red clay.
yds. N.N.E. of <i>Stalden</i> - - -	"	E. 25° S.	? glacial.
<i>Barroo Ned</i> , <i>Calf Sound</i> , 110yds. E. of <i>ak Noy</i>	striped slate	S. 15° E., crossing, S. 40° E.	
at <i>Cronk Moor</i> , W. side of <i>Spanish</i>	"	S. 30° W. and others	
at <i>Spanish Head</i> above <i>Slea ny Bery</i> -	"	S. 30° W., crossing, S. 20° E.	
re of moor N. of <i>Spanish Head</i> , 300yds.	"	S. 30° W.	
<i>Cronk Moor</i>	"	"	
dge of moor, 350yds. N. of <i>Cronk Moor</i> -	"	S. 15° E., crossing S. 20° W.	good.
do. 100yds. N.E. of last - - -	"	S. 30° E.	good.
west of <i>The Chasms</i> , above stone circle of one of <i>Chasms</i> - - -	grit	W. 40° S.	
inland N.E. of <i>The Chasms</i> - - -	"	W. 40° S.	
land; roadside 350y s. W. of <i>Grant's four</i>	striped slate	S. 20° W.	
and; near hill-top 38 yds. E.N. " of <i>r lighthouse</i>	"	S. 20° E.	
land; near hill-top 32 yds. E.N.E. of <i>r lighthouse</i>	"	S	altitude about 400 ft.

PART III.
ECONOMIC GEOLOGY.

CHAPTER XII.
THE METALLIFEROUS VEINS OF THE ISLAND.

HISTORICAL AND INTRODUCTORY.

In proportion to its area the metalliferous wealth of the Isle of Man has been great. Two of its mines have stood, for a long series of years, in the first rank in the British Islands for productiveness, respectively, of silver-lead and of zinc. These metals have constituted its principal riches, but copper-pyrites and hematite-iron has also been raised in marketable quantity. Of ores of nickel and antimony only minute quantities have been found, while of gold the reported occurrences are not well established (p. 549).

As veins yielding traces of the useful metals are frequently exposed in the cliff-sections, it is not surprising to find that they attracted attention at an early date, and are mentioned in the ancient records of the Island.

The great lode of Bradda Head (see p. 530), with its gangue of white vein-quartz cutting vertically through the cliffs of dark slate, stands up so conspicuously when viewed either from land or sea that it must have received notice as soon as this part of the Island became known to men acquainted with the use and mode of occurrence of its metals.

Hence, so far back as history goes we hear of this lode; and the miners of later days have found workings of unknown date in which the ore had been extracted by the use of feather-wedges, a method abandoned upon the introduction of gunpowder.¹ These old workings have been vaguely assigned to "the Romans"; but though the Island was known to that nation the absence of Roman antiquities renders it improbable that any attempt was made by these invaders to colonise it.

¹ Cumming, "Isle of Man," p. 306; also Berger, Trans. Geol. Soc., vol. ii. p. 51.

We are informed by Mr. A. W. Moore, the historian of the Island, that in the course of his researches¹ he finds the first mention of the Manx Mines in 1246. The island was at that time still under the dominance of Norway; and its King, Harald II, granted a charter by which the monks of Furness Abbey obtained the right to work the mines.² The previous existence of the mines is thus distinctly implied.

Cumming notes that "it is stated in Chaloner's 'Caledonia' (vol. iii., p. 372) that John Comyn, Earl of Buchan, obtained from Edward I. a license to dig for lead in the Calf of Man to cover eight towers of his Castle of Cruggleton in Galloway. In the course of the 15th, 16th, and 17th centuries, the noble family of Stanley appear to have sought for copper in the same neighbourhood; traces of their labours remain. The ore discovered, though not abundant, was rich in quality, producing six pennyweights of copper per ounce of ore."³

From Mr. Moore's researches we learn that in 1406 "mines of lead and iron" were included in the grant of the Island to Sir John Stanley by Henry IV.; and in 1422 it was ordered that the lord's mine should be managed by his "Lieutenant, Receiver, and Comptroller,"⁴ who had to see that the miners did their duty. In the middle of the 17th century, Chaloner mentions that Capt. E. Christian found the Ore of Lead at "Mine-hough" [Mine-howe?] or Bradda Head to contain much silver.⁵ After the Restoration, mining was prosecuted more systematically; and from that time both lead and copper seem to have been diligently sought, the lord letting his rights in the mines on condition of receiving one-fifth of the produce. In 1668 a lease of all the mines in the Island, with leave "to erect a smelting mill, or more than one, for the smelting of the oar-mynes and minerals," was granted to two merchants, one of London, and one of Liverpool.⁶

In the following year Charles, the 8th Earl of Derby, at that time Lord of Man, "being by good reasons persuaded y^t there is plenty of coales" in the Island, ordered the Governor to institute a search for it.⁷ In 1699 the lord's fifth of the lead and copper ore amounted to 32 tons 13 cwt. About this time also the hematite iron-ore of Maughold received attention, Mr. Moore finding it on record that in the year 1700 there was shipped from the mine at "Daunane" (Drynane, see p. 126) 227½ tons of this ore.⁸

¹ Since this chapter was written, Mr. Moore has included an account of the progress of Manx mining in his "History of the Isle of Man" (2 vols. 8vo., London, 1900). Vol. ii., pp. 960-971.

² "Cott. MSS., Manx Soc., vol. vii., pp. 79-81."

³ "Isle of Man," p. 307.

⁴ "Statutes," vol. i., p. 19.

⁵ See reprint by Manx Soc., vol. x., p. 8.

⁶ "Loose sheets in Seneschal's Office" [A. W. Moore].

⁷ *Ibid.*

⁸ *Ibid.*

Governor Sacheverell, in his "Account" of the Island published in 1702, writes:—"I am informed, since I left the Island, they have discovered very good mines of Lead, Copper, and Iron, and great probability of Coal."¹

The strenuous efforts made about this time to encourage mining are illustrated by the following notice, published in 1714 (for copy of which we are indebted to Mr. Moore).

'Forasmuch as our hon^{ble} Lord hath been pleased for the discovery and finding out mines within this Island to send over an order that any person who shall find out any veines of Lead or Copper such as shall be thought fitt for working by the Steward or overseer of the said workes shall not only have paid down to them fourty shillings as a reward, but shall have the preference of working the said mines and three pounds a ton for every ton they shall get, delivering unto the Steward a fifth part of what ore they shall raise after the same is cleansed and made merchantable, provided they begin and prosecute the said work within three months."²

A few years later, Bishop Wilson wrote as follows:—"Mines of coal there are none, though several attempts have been made to find them; but of lead, copper, and iron there are several, and some of them have been wrought to good advantage, particularly the lead; of which ore many hundred tons have of late been smelted and exported. As for the copper and iron ores, they are certainly better than at present they are thought to be, having been often tried and approved of by men skilled in these matters: however either through the ignorance of the undertakers, or by the unfaithfulness of the workmen, or some other cause, no great matter has as yet been made of them."³

From this statement it appears that the metals were raised in the same relative proportions at that time as at present, excepting that the zinc-blende associated with the lead-ores, formerly of little or no value, is now a product of considerable worth. The repeated attempts since made to work the veins of copper and iron have met with no lasting commercial success, and it seems to have been demonstrated that those ores do not occur in sufficient quantity for profitably winning under current conditions of price.

In the above accounts the only localities actually mentioned are Bradda Head, The Calf, and Maughold, all places where the metalliferous veins are visible in the cliffs, though it is probable that trials had also begun on the richer deposits of the interior. Dr. Berger in his description of the mines in 1814 has the following note:—"Mr. Fitz-Simmons, who is preparing to publish an extensive work on the ancient History of the Isle of

¹ Manx Soc. Reprint, p. 17.

² "Lib. Scacc." [A. W. Moore].

³ Bp. Wilson's "History, etc.," in Camden's "Britannia," 1772, p. 392. Manx Soc. Reprints, vol. xviii., pp. 94-5.

Man, states that mention is made of the mines of the Isle in the time of Sir Stanley 1st and 2nd." (*Foot note*—"The first Sir Stanley appointed King of Man, was by grant from King Henry 4th in the year 1407.") "Those at Brada, he believes, were first wrought; whether those at Foxdale were then opened may be doubted; those at Laxey were opened and wrought by a mining company of Cumberland, about the commencement of the last century"

"Mr. W. Geneste informs me further that he lately found in some books (titled Charge of the Revenue) in the Duke's office in Douglass (called the Seneschal's office) that the last Earl of Derby had the mines wrought, paying the workmen at the rate of £3 Manx per ton for the ore (lead) raised. In 1709, he paid the miners for about 70 tons; from 1709 to 1713, about 30 tons yearly. A new smelting house was built in 1711. The workings of the mines was totally suspended about 3 years ago."¹

Among the papers preserved in the Office of Woods and Forests in London relating to the mines of the Island are several relating to a grant, made in 1679 by King Charles II. to Charles, Earl of Derby, of a Lease of "all Mines Royal of gold or silver, or holding gold and silver to such a proportion as according to the Laws of the Realm of England doth make the same a Mine Royal." This lease had expired by the failure of the Heirs male of the grantee on the death of James, Earl of Derby in 1735, but was revived on the petition of John, Duke of Athol in 1780, upon a declaration made by P. J. Heywood, a former Deemster of the Island:—"That he is enabled to declare of his own knowledge and from what he hath heard, that there are not any mines of Gold or Silver in the said Island; that the only mines which now are or ever were wrought in the said Isle, as he hath heard and believes, are Mines of Lead and Copper. Except that he hath heard some Mines of Iron have been worked formerly, and that he hath been informed by persons experienced in the knowledge of mines that there is a proportion of silver in the Lead-mines now working, but so small as by no means to answer the expence of assaying and separating."²

Feltham, in 1798, describes the mining work then in progress at Laxey and Foxdale, but found the Bradda mines closed.³

Woods, in his account of the Island published in 1811,⁴ gives some interesting data respecting the mines then existing. These were at Laxey, Foxdale, and 'Breda' Head; and he mentions also deserted shafts of lead-mines with rubbish-heaps between Port Erin and Kirk Arbory, no doubt referring to those since reworked as the Ballacorkish or Rushen mines (see p. 532). He speaks of Bradda as a copper mine, but did not visit it. Foxdale he found deserted and drowned (see p. 500). Laxey was being worked by two levels from the banks of the river and yielded

¹ Trans. Geol. Soc., vol. ii., p. 51.

² In a Report of the Surveyor-General to the Royal Commission

³ "Tour through the Isle of Man," pp. 213, 243.

⁴ "Account of the Isle of Man," pp. 10-20.

silver-lead, blende and copper (see p. 519). He mentions that a small quantity of compact brown ironstone occurred immediately under the breccia (Carboniferous Basement Beds) in the Silverburn near the mill below Athol Bridge. The old level at that place to which reference was made on p. 197 was perhaps in connection with this ore.

Quayle also published details respecting some of the workings in 1812.¹

Macculloch, in his work published in 1819, discusses the metalliferous veins of the Island at some length.² He notes that the mines were all abandoned, with no prospect of renewal—a statement which in view of the later highly successful results obtained from Foxdale and Laxey may afford some prospective encouragement to the hopeful adventurer on old workings in the Island. He speaks of Laxey, Brada Head and Foxdale as the three principal veins, but found that work had been carried on also at Ballacorkish and Glensash (Glenschass, see p. 536) near Port St. Mary; and some other small north and south veins near Port Erin were pointed out to him by old miners, (probably at Bay Fine and Calf Sound, see p. 532).

The following are the "Mines and Minerals" catalogued in the "Schedule of the Property" conveyed by the Duke of Athol to the Crown in 1827-8 (MS. in Office of Woods and Forests):—

LEAD MINES.	YELLOW OCHRE
New Foxdale.	Mallew.
Old Foxdale.	
Flappy Vein.	LIME STONE.
Balla Corkish Vein.	Port le Mary.
Silver Bourne Vein.	
Glen Chass Vein.	BLACK LIMESTONE
Bradda Head Vein.	Pool Vasle [vash].
Laxey Vein.	
COPPER MINE.	SLATE.
Bradda Head.	South Barrule.
IRON STONE.	STONE QUARRIES.
Maughold Head.	Gob e Valley.
POLISHING POWDER.	Spanish Head.
Ballastole.	COAL

Among other papers relating to this transfer preserved in the Woods and Forests Office in London are copies of the leases under which the mines were worked, and plans showing the extent of the development of the more important mines up to that time. These plans will be referred to when the mines are separately described.

¹ "General View of the Agriculture of the Isle of Man," pp. 9-10.

² "Western Isles," vol. ii., pp. 574-577.

The third and fourth decades of the 19th century marked a great revival and development of the Manx mining industry. After that time its steady progress may to some extent be traced in the Mining Statistics published in an early memoir of the Geological Survey and in the Records of the School of Mines (see pp. 495-8).

Cumming gave a full account of the condition of the mines as he found them in 1845-1848.¹ He notes that the Foxdale mining ground, extending eastward across the northern side of South Barrule from Glen Rushen, had hitherto proved the most productive on the Island; and thinks that the proximity of the granite had very beneficially affected its mineral riches. The company then working this group of mines generally employed about 350 men and boys, and the average raising of silver-lead ore for the previous ten years had been about 2,400 tons per annum. Laxey also, he states, was being worked by a new company employing 300 men and raising 60 tons of lead, 200 tons of blende mixed with lead, and 5 tons of copper ore per month; the deepest working being 130 fathoms below the adit-level. The other mines which he mentions are the Ellerslie on the Bishop's Barony near Crosby (see p. 516), which was being worked without success; a Copper Mining Company in Maughold parish, also unsuccessful; and the iron mines in the same parish, in which about 70 men were employed and ore raised to the extent of about 500 tons per month.

During the ensuing twenty or thirty years the great prosperity of the Foxdale and Laxey companies led the investing public to take shares readily in Manx mining enterprises, and stimulated the search for metals in every part of the Island. Numerous new companies were formed, and mines established on the slenderest prospects, with of course almost uniform ill-success. In some cases no ore whatever was obtained; oftener the vein yielded a little lead, zinc, or copper, in quantity too small to be marketed; while in a few instances sufficient ore was found to be worth selling, but less than paid the working expenses. The wrecks of these mines, with their ruined buildings and plant, are strewn here and there over the whole area occupied by the Manx Slates. It is impossible at the present time to obtain in the Island definite information regarding many of these; but fortunately, through the courtesy of the Commissioners for the Woods and Forests, we have been allowed access to the reports made annually between the years 1857 and 1888 by the eminent mining authority, Sir W. W. Smyth, who, in his official capacity as Chief Mineral Inspector for that department, examined most of the workings at the period of their activity, and reported fully. We are also indebted to Mr. W. H. Rowe of Douglas, for placing at our disposal his collection of plans and details of old mines. From these and other sources duly acknowledged in the context, the descriptive accounts of these ventures given in the succeeding pages have been prepared.

¹ "Isle of Man," Appendix K., pp. 306-311.

GEOLOGY OF THE METALLIFEROUS VEINS.

General Characters.

While the lodes which have been mined to commercial advantage in the Isle of Man are only two in number, viz., that of Foxdale and that of Laxey, it has been demonstrated by the numerous other workings that ores of lead, zinc, iron and copper are present in a minor degree in veins in almost every part of the Manx Slate Series. These veins have in all cases the character of infilled fissures which break across the stratification of the rocks. Relative displacement of the walls of these fissures has probably occurred in most cases, but usually only to a slight amount; and it is exceptional to find indications of considerable faulting along them. The principal vein is generally accompanied by rudely parallel veins and branches which are sometimes in themselves metalliferous, the whole forming a more or less complex group. Occasionally they are broken and displaced by later transverse faults, as will subsequently be described. Almost invariably they are inclined, at angles of from 5° to 30° or more degrees from the vertical, this "hade" varying in amount as the vein is followed downward, but usually constant in direction. In rare instances the "hade" is temporarily reversed, a change considered by the miners to be unfavourable to the productiveness of the lode.

The veins are subject to great and sudden variations in breadth and in mineral contents, the metalliferous deposits rarely form more than a small proportion of their infilling, the greater part of the fissure being occupied by crystalline quartz, calcite, dolomite, with sometimes a little barytes, fluor-spar, etc., and by breccia and decomposed material derived from the walls. Gas- or water-filled cavities known as "lochs" or "vughs" are likewise frequent. The valuable ores sometimes occur in definite ribs in the vein-stuff, and sometimes in disseminated crystalline grains, or in both forms combined. It is clear that the crystalline constituents, both metalliferous and non-metalliferous, have been slowly deposited in open cavities. In some cases, mostly in the Foxdale Lode, there are indications of movement of the walls after partial infilling of the fissure, causing portions of the vein-stuff to be displaced and brecciated. The fissures have been found to extend vertically, with or without ore, as deeply as the deepest mining works have gone, viz., not far short of 2,000 feet below the present surface at Foxdale and at Laxey; laterally, the Foxdale lode in one or another of its branches has been traced almost continuously for $2\frac{1}{2}$ miles, and the Laxey Lode for over a mile; but in most cases the veins have been found to split up or otherwise become indistinguishable within much shorter distances.

Direction of the Lodes.

The main lode-system at Foxdale has a nearly east-and-west course, and the smaller veins at the old Cornelly Mine

a mile north of Foxdale, and at the Bishops Barony Mine three miles east of Foxdale, have also this direction; but at Laxey, Snaefell, Ballacorkish, Bradda, and in fact at almost all the other workings from which ore has been obtained the direction of the lode has been approximately north-and-south, or more strictly, a little (5° — 30°) to the west of north and east of south. In only one or two unimportant instances has any ore been found in N.W. and W.N.W. veins; while apparently not a single case of a productive north-easterly vein is known, although this is the direction of strike of the rock-masses and of innumerable quartz-veins accompanying planes of cleavage, crushing and fracture (see pp. 86–7). It is true that the predilection of the miners for north-and-south veins has led to these being tested in far greater numbers than those in any other direction, and that this selection may in some degree have affected the result; but the extent to which veins of every kind have been cross-cut in underground workings on the productive lodes is sufficient to prove that the occurrence of the metalliferous ores in other than the recognised directions must be extremely rare.

The north-and-south veins are rather frequently dislocated by normal faults, known to the miners as 'slides,' which usually strike about E. 20° N.—W. 20° S., or approximately at right angles to the metalliferous vein.. Several of these have been observed in the Laxey Mine (see p. 521) and others at Ballacorkish (p. 527), Snaefell (p. 535) and one or two other places (pp. 528, 532). The amount of vertical displacement which they represent is as a rule small; but if the disturbances by which the Laxey vein is lost southward, and by which the Ballacorkish vein is broken at the "Great Douk Lode," be due to faulting, these cases may be of great extent. It is not clear whether the north-and-south lodes received their metalliferous infilling before or after these transverse dislocations took place; with one supposed exception (p. 522) the 'slides' have never been found to contain ore, but some of the facts at Laxey suggest that the principal deposition of the metals took place there subsequent to the faulting of the lode (p. 522).

At Foxdale, while the chief productive lode strikes east and west, this intersects north-and-south metalliferous veins both in the central portion of its course, and farther west at Beckwith's Mine; and in the latter case the E.—W. lode is said to have thrown the N.—S. lode at the intersection (p. 505), thus playing the rôle of a 'slide.' In the Foxdale Mines slickensided surfaces are abundant, and the striations are generally nearly horizontal, showing that some degree of lateral movement has taken place along the line of the lode; moreover, the metalliferous vein-stuff is in places broken up, sometimes into partially rounded blocks, and recemented by undisturbed material subsequently introduced, showing that there has been movement along the fissure after an interval of quiescence.

It seems possible that the later movement may have taken place here at the time of the cross-faulting of the N.—S. lodes

in other districts, and that the Foxdale vein was affected along, and not across its course because of its E.—W. direction.

A point of importance in regard to the position of the lodes is, that all the larger and more productive, including Bradda, Ballacorkish, Foxdale, Laxey, and Maughold Head, occur on or in the vicinity of the structural axis of the Manx slates, near where the dominant dips of the folded strata and of the cleavage form an anticline. As elsewhere shown (p. 118), this axis is probably the centre of a synclorium of the slates as a whole; but it is remarkable that in many mining districts abroad, *e.g.*, in Nova Scotia and Queensland,¹ a close association of metalliferous deposits with anticlines of folded strata has been observed, though not in veins of the Manx character.

Age of the metalliferous lodes and relation to the Olivine-dolerite dykes.

While from the limited range of Manx stratigraphy direct evidence as to the period at which the metalliferous fissures were formed is not forthcoming, we possess sufficient data to show that it must have been comparatively late in the geological history of the Island. It was certainly later than all the Pre-Carboniferous earth-movements and dyke-injections described in a previous chapter (p. 71-2), by which the Slate Series was packed into folds, brecciated, foreshortened by overthrusts, and interpenetrated by basic and afterwards by granitic intrusions.

The segregation-veins of quartz and other minerals which were formed so abundantly during the later stages of these movements contain no metals of economic value; and the metalliferous fissures have been cleanly gashed through rocks in which all the above indications of earth-movement are present, and are clearly subsequent. The presence of copper pyrites in a vein in the Carboniferous Basement Conglomerate at Langness (p. 538), and of galena in a similar vein in the Carboniferous Limestone at Castletown (p. 537), brings down the date of, at any rate, some of the metalliferous deposits into Post-Carboniferous times. The only 'solid' rocks newer than Carboniferous accessible to observation above sea-level in the Isle of Man are the intrusive dykes of olivine-dolerite, which, on grounds already discussed (Chap. VIII, p. 327), are believed to be of Tertiary age. The study of the relationship of these dykes to the lodes has led me to the unexpected conclusion that, although the fissures were in existence before the date of these intrusions, some part of their metalliferous infilling was of later date. The grounds for this conclusion are fully stated in the descriptive details of the Bradda, Ballacorkish, Langness, East Foxdale and other mines, and will here be only briefly recapitulated.

At North Bradda, Ballacorkish, and Langness there is evidence to show that dolerite dykes, following the usual north-westerly

¹ Victoria Government Blue-book; Dept. of Mines; Reports on the Bendigo Gold-field, by E. J. Dunn, pp. 9-13 (Melbourne, 1896).

course, have been diverted northward for a short space on intersecting the fissures. In the first-mentioned place, where the lode is of great size and clearly revealed in the cliff, it is seen that the dyke is intrusive into the vein. But at Ballacorkish and East Foxdale, portions of the metalliferous lodes have been found in the underground workings to intersect the igneous rock (see Smyth's reports quoted on pp. 515 and 534), and the ores (sulphides) lie alongside the margin of the dyke-rock, in positions which they could not have occupied before or during the injection of the molten matter; and similarly at Langness, where the ore slightly interpenetrates the dolerite. Besides the places above mentioned, smaller quantities of the metalliferous ores have been found in the vicinity of olivine-dolerite dykes at Kerroo-mooar (p. 546), Glen Auldyn (p. 545), Maughold Head (p. 541), and Castletown Harbour (p. 537); but in all except the last case no evidence is now available as to the exact relationship.

It is of course possible that scattered ores already in existence in the fissures may have been displaced and concentrated into larger bodies by the invasion of the dykes; but it seems more likely that the deep-seated channels which permitted the upward egress of the molten rock may also have served, at a somewhat later stage of the same period of thermal activity, as conduits for the vapours and waters which supplied the crystalline infilling to the reopened fissures.¹

It does not follow, however, that the whole of the Manx metalliferous veins are of this age; for it is only in a few instances, and these not of the first importance, that the connection between the dolerite and the ores has been observed; and, moreover, the majority of the olivine-dolerite dykes are not known to be accompanied by ore-deposits. All that can be learned from the evidence is that where the dykes of this late age are in contact with the metalliferous accumulations, the latter are the newer. As no association of olivine-dolerite dykes with ore deposits appears to be known in Western Scotland and Northern Ireland where these intrusions are so numerous, there must be some additional factor in the local conditions of the Isle of Man which has favoured the production of the metals in the veins. What this may be has not yet been discovered.

The outcropping of the metalliferous veins and of the dolerite dykes at the present surface shows how extensive must have been the erosion in the area during later Tertiary times, as the infilling of the fissures in both cases can only have occurred at some considerable depth.

I was not aware until after the above passages were written that my colleague, Mr. J. G. Goodchild, had some time ago reached a similar conclusion in regard to the metalliferous veins of another district by a different chain of reasoning. The

¹ Sir W. W. Smyth's description of the quiet and undisturbed condition of the delicate fibres of Plumosite in the Foxdale lode, quoted on p. 503, has direct bearing on this question.

following quotation from his suggestive paper entitled "Some Observations upon the Mode of Occurrence and the Genesis of the Metalliferous Deposits,"¹ will show that the Manx evidence is in close agreement with his results.

"As bearing upon the age of the North of England lead-veins one or two points remain to be considered. The faults wherein the veins occur probably date back in many cases to very remote geological periods. As zones of disturbance and of dislocation, many of them certainly may be referred to periods long anterior to the date of the rocks they now affect at the surface. There is plenty of evidence to show that, as zones of weakness, they have acted as faults again and again at various periods since. The fault breccias are scrunched and slickensided in a manner that points to the repeated exertion of powerful mechanical forces in times past. In remarkable contrast to this evidence of powerful grinding and crushing is that afforded by the crystalline contents of the veins. There may be, in a few instances, some kind of evidence of these vein-minerals having been disturbed since they were formed; but as a rule the evidence tends to show that since the date of formation of these minerals there has been no vertical displacement of the opposite cheeks of the fault. Large masses of crystals occur without the slightest sign of any break during their growth from first to last, and the crystalline faces of many of the minerals, such as Fluor, Baryte, Galena and others, are just as perfect as when the minerals were first formed. The significance of this very common feature of mineral veins does not seem to have been generally perceived."

"Another equally well-known feature in connection with mineral veins calls for remark here. This is the 'comby' structure of lodes, and the evidence of the deposition of vein minerals in successive layers. This clearly points to the fact that during the filling of the vein there were occasional interruptions of deposition, which were contemporaneous with more or less lateral disruption of the veins and their contents. After the formation of the earliest stages of the comby structure there has been no displacement along the plane of the fault."

"Such a condition of things, extending over a large area, can only have obtained under conditions of upheaval. This seems to indicate that the introduction of the lead ores of the North of England took place at, or about the close of, the last period of upheaval. This, by independent reasoning, I have inferred to be contemporaneous with the last manifestations of volcanic energy in Tertiary times; and all the evidence yet brought forward seems uniformly to support that conclusion" (pp. 56, 57).

In many other parts of the world it has been proved that certain metalliferous veins have received their infilling at comparatively late periods in geological history and in association with the intrusion of igneous rocks. If we take, for example, Part III. (Economic Geology) of the 18th Annual Report of the U.S.

¹ Proc. Geologists' Assoc., vol. xi. (1888-9), pp. 45-68.

Geological Survey, which came to hand while this chapter was in preparation, we find an account (p. 69) of the celebrated Treadwell-Mexican Gold Mine on Douglas Island, Alaska, by G. F. Becker, in which it is stated that the mineralization of the lode is probably connected with the intrusion into it of a vein of analcite-basalt, the author concluding that "the basalt was injected after the mineralization began, but before it had ceased"; he adds, "so far as I know this is the first known case of an association of analcite-basalt with ore generation." The age of the intrusion is not definitely established, but is supposed to be either Late Mesozoic or Tertiary.

Moreover, in the same volume three out of the four other reports on mining districts, in widely separated parts of the Western States, embody the conclusion that the metalliferous infilling of the veins must be assigned to periods of eruptive activity in Tertiary (or in one case possibly Cretaceous) times: these are "On the Judith Mountains of Montana," by W. H. Weed and L. V. Pirsson (veins not older than early Tertiary, p. 463); "On the mining districts of the Idaho Basin," by W. Lindgren (veins probably Cretaceous or early Tertiary, p. 631); and "On the Telluride Quadrangle, Colorado," by C. W. Purington (veins not older than Late Tertiary, p. 825).

'Country'-rock of the Lodes.

The Manx metalliferous veins are developed principally in that portion of the Manx Slate Series which is intermediate in character between the grits on the one hand and the clay-slates on the other. Their usual matrix is the bluish-grey thin-bedded flags or flaggy slates which consist of a more or less intimate admixture of argillaceous and fine-grained sandy or silty material. In no case has a productive lode been found among the quartz-veined grits ("Agneash and other Grits," of published map); and where belts of this character have been encountered in underground workings, as at North Laxey and in the northern extremity of Great Laxey, the vein has been found to contract or become 'tight,' and to lose its value. On the other hand the homogeneous dark-blue "Barrule Slates" have been found equally barren; and where bands of this composition have been passed through, as at Snaefell and other places, the lode has become soft ('douky') and shattered, splitting up into small branches and losing its individuality. At Foxdale the main E. and W. lode, and also one of the N. and S. cross-courses (Magee's), has been followed downward from the slate into granite, and has been found equally as productive in the one rock as in the other, though the quality of the galena has shown a remarkable variation, that in the slate being richer in silver than that in the granite.

In this locality the opinion, alluded to by Cumming,¹ is commonly held that the metalliferous vein owes its riches to the

¹ "Isle of Man," p. 308.

granitic intrusion. But it is clear not only that the granite was consolidated, but also that its offshoots were affected by post-consolidation movements (p. 316) long before the lode was formed. Similarly at Laxey, the lode cuts across elvans given off from the Dhoon Granite, in which incipient cleavage had been produced by earth-movement subsequent to their consolidation (p. 521); and at the old Cornelly Mine, a mile N. of Foxdale, where massive granite was found beneath the slate (p. 517), the lode traversed both rocks. At Bradda, Ballacorkish, Snaefell, and North Laxey, considerable ore bodies occur in the slate-rocks where there is no reason to suspect the proximity of granitic intrusions; and the highly productive western portion of the Foxdale main lode, (Beckwith's Mine, p. 504), lies amid slates nearly 2 miles beyond the proved underground extension of the granite. The rich vein at Laxey, again, is about a mile distant from the nearest outcrop of the Dhoon Granite; while other veins in close proximity to that intrusion have proved barren or nearly so (p. 528). Hence the whole of the facts tell against the supposition that the metalliferous deposits were a direct result of the granitic eruptions.

In an indirect manner, however, it is possible that the Foxdale Granite, long after its consolidation, may have favoured the production of the lode, by affording a massive homogeneous rock-basement, in which a fissure produced by unequal earth-movement might descend to great depths and remain sufficiently open to permit the ascent along it of the vapours and solutions from which the empty spaces received their infilling. The broad shelving laccolitic outline of this granite (p. 166) would be more favourable to the production of such a fissure than would be the case in the Dhoon Granite, which appears to descend as an irregular pipe-like core with steep walls (p. 144).

The same explanation may be applied to the distribution of the veins in the sedimentary rocks. Where these were of a character to break cleanly to considerable depths, and to preserve an open space when fissured, as in the case of the firmly packed and welded mass of Lonan flags enclosing the Laxey lode, productive metalliferous veins have been formed: but where the rocks were, like the Agneash Grits, of such a character that regular fissures could not readily be produced in them; or, like the Barrule Slates, where if produced, such fissures would be filled with the broken debris of the walls, the conditions were unfavourable either for the percolation or deposition of the ore-bearing solutions, and the veins are consequently scanty and of no economic value. This explanation seems adequate for the known occurrences of ore in the Island; but fails to account for the fact that there are large tracts of the firm slaty flags apparently equally favourable for the production of lode-conditions, in which only inconsiderable quantities of ore have yet been discovered. Here again some additional factor in the deep-seated structure, to which we have no clue, is probably involved.

Association of the Ores in the Lodes.

On this point but little information has been obtained. The lead and zinc ores (sulphides) are usually found together, but the relative quantities are extremely variable; so that while at Laxey zinc-blende is by far the most abundant ore, at Foxdale the quantity present is too insignificant to be recognised commercially. Copper, in the form of pyrites, generally occurs, in very thin strings or finely disseminated around the outskirts of the other ore-bodies, as at Laxey, where its appearance in the southward drivings heralded the deterioration, of the lode (see p. 520); at Foxdale it is rarely found and in very small quantities (see Smyth's report in 1883 quoted on p. 511). Pyrites and chalybite are more or less present in all the lodes, the latter sometimes in large bodies at Foxdale.

The hematite ore of the Maughold veins, as suggested on p. 291, may have been introduced into the lode when the slates were overlapped by Triassic strata.

Lists of the minerals of the individual lodes and particulars respecting the rarer varieties are given in the subsequent detailed descriptions of the mines.

Notes on the Mineral Statistics since 1845.

After the close and systematic search which has been made in every part of the Island, we may presume that the relative importance of the various lodes has been well established, and that no considerable body of ore presenting surface indications can have been overlooked, though there is, of course, the possibility that such may remain still undiscovered beneath a superficial covering of drift. As previously mentioned, while the valuable ores have been found in small amount in many veins, the commercially successful mines are and apparently have always been confined to two lodes—that of Foxdale and that of Laxey, though considerable bodies of lead and zinc ore have been met with also in the mines of 'Snaefell,' 'North Laxey' in the Cornah Valley, and 'Ballacorkish'; and of hematite in Maughold parish. From all the other workings combined the total quantity is inconsiderable. From the depth to which the principal mines have now been sunk, we must also conclude that the average output of the last fifty years is unlikely to be maintained in the future.

LEAD-ORE.—The table given on pp. 495–8 shows that between 1845 and 1850 the average output of lead-ore was 2,300 tons per annum, of which at first six-sevenths, and afterwards two-thirds was contributed by the Foxdale group of mines, and practically the remainder by Laxey. A steady increase during the next five years brought the total output of this ore in 1855 up to 3,573 tons, of which three-fourths was from Foxdale, and the remainder

from Laxey. A decrease then set in, so that until 1864 the annual output ranged, in round numbers, between 2,500 and 2,800 tons. In that year however the contribution from Laxey was greatly augmented; and in the following year equalled that of Foxdale, bringing the total up to 3,143 tons of lead-ore. In 1871 the grand total of 4,645 tons was reached, of which Laxey yielded a half, Foxdale rather over a third, and eight smaller mines the remaining sixth. There was a drop of 1,000 tons in 1872 owing to a decrease of that amount from Laxey; but from 1873 to 1877 inclusive the total annual output of the Island remained steadily between 4,200 and 4,400 tons, the Foxdale contribution maintaining, as for many previous years, remarkable regularity at about 1,600 to 1,700 tons. In 1878 the returns fell below 4,000 tons, Laxey sinking again, and permanently, to the second place as a lead-producer. But this deficiency was more than made up in succeeding years by Foxdale, which swelled the output to high-water mark at 6,868 tons in 1885, two-thirds of which was from this mine and less than a quarter from Laxey. From 1884 to 1893 inclusive the total yield of lead-ore remained between 6,000 and 6,700 tons, the decline of Laxey meanwhile continuing, so that in the last-named year its proportion was less than one-seventh, while Foxdale yielded three-fourths and three other mines the remainder. Since that date, though Foxdale has maintained its high productiveness—its yield of 4,800 tons of lead-ore for 1894 being the greatest in the history of the mine—the deficiency from the other mines has diminished the total output of the Island to 3,843 tons for 1900.

ZINC-BLENDE.—The only other metal deserving special notice is zinc; and its history is practically that of the Laxey Mine, as except during a short period of productiveness at Snaefell, the other sources of this substance in the Island have been unimportant. In 1854 the returns of blende from Laxey were 1,435 tons, rising suddenly in the following year to 3,989 tons, and from that time until 1861 ranging around 3,000 tons more or less. Then follow great fluctuations, so characteristic of this mine, the record for 1862 being 691 tons; for 1863, 2,298 tons; for the four following years, between 4,960 and 5,488 tons; in 1869, 7,208 tons; and so on, until in 1875 the returns show 11,753 tons of blende from this mine, and 11,898 tons from the whole Island, a quantity which has not been since attained.

During the ensuing decade, the average was about 6,000 tons, ranging from about 2,000 above to 2,000 below this figure. But since 1885 there has been a continued decline which brought down the total for 1896 to 1,180 tons of blende from Laxey and 1,489 tons from the whole Island, with a slight recovery to the total of 2,009 tons in 1897, 2,602 tons in 1899, and 2,124 tons in 1900.

The following table gives the total annual output of the Manx Mines recorded in official returns.

ISLE OF MAN MINING STATISTICS.

TABLE showing TOTAL OUTPUT OF MANX MINES.¹

Year	1826	1827	1828	1829	1830	1831	1832	1833	1834	1835	1836	1837	1838	1839	1840	1841	1842	1843	1844
Lead ore (containing silver, as below),	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Zinc ore . . .	—	—	—	—	—	—	—	No returns available	No returns available	before 1845.	before 1854.	—	—	—	—	—	—	—	—
Copper ore ² . . .	23	—	26	161	238	238	341	249	268	77	89	90	121	183	276	368	406	207	46
Iron ore . . .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Umber, Ochre, etc. . .	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Silver, estimated quantity contained in lead ore	—	—	—	—	—	—	—	No returns available	—	—	before 1851.	—	—	—	—	—	—	—	—

¹ Compiled from Mem. Geol. Survey, vol. II (1848) pp. 703-715; Records of the School of Mines, vol. I. (1853), pt. 4; Mineral Statistics, 1853-1898.² The figures for the first twenty-two years are derived from "Sales at Swansea from English Mines," Mem. Geol. Survey, vol. II, p. 715.

ISLE OF MAN MINING STATISTICS.—Continued.

TABLE showing TOTAL OUTPUT OF MANX MINES.

Year	1845	1846	1847	1848	1849	1850	1851	1852	1853	1854	1855	1856	1857	1858	1859	1860	1861	1862
Lead ore (containing silver, as below).	Tons. 2,259	Tons. 2,316	Tons. 2,575	Tons. 2,521	Tons. 2,526	Tons. 2,175	Tons. 2,660	Tons. 2,415	Tons. 2,460	Tons. 2,900	Tons. 2,578	Tons. 2,318	Tons. 2,056	Tons. 2,457	Tons. 2,464	Tons. 2,810	Tons. 2,719	Tons. 2,508
Zinc ore . . .	—	—	—	—	—	—	—	—	—	1,438	2,990	2,000	2,917	2,777	—	2,181	2,225	691
Copper ore . . .	70	92	60	—	—	—	—	—	—	64	—	125	260	408	254	260	785	942
Iron ore . . .	—	—	—	—	—	—	—	—	—	—	2,240*	—	—	565*	1,232*	1,671*	967*	647*
Umber, Ochre, etc. . .	—	—	—	—	—	—	—	—	—	164	—	151	—	120	—	—	116	—
Silver, estimated quantity contained in lead ore.	—	—	—	—	—	—	22,980	26,700	47,105	52,392	55,208	60,222	48,016	46,985	54,974	60,170	67,282	70,592

* Heematite.

TABLE showing TOTAL OUTPUT OF MANX MINES.

Year	1863	1864	1865	1866	1867	1868	1869	1870	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880
Lead ore (containing silver, as below).	Tons. 2,561	Tons. 3,118	Tons. 3,143	Tons. 3,494	Tons. 3,799	Tons. 4,290	Tons. 4,302	Tons. 4,604	Tons. 4,645	Tons. 3,529	Tons. 4,371	Tons. 4,301	Tons. 4,429	Tons. 4,363	Tons. 4,464	Tons. 3,920	Tons. 4,368	Tons. 5,119
Zinc ore	2,298	5,363	5,488	4,980	5,361	3,273	7,219	4,177	5,768	3,123	5,520	7,010	11,898	8,669	9,013	9,569	7,427	7,507
Copper ore	1,298	127	1,317	294	400	462	459	373	180	823	—	61	—	75	52	30	20	35
Iron ore	339*	—	120*	—	—	250*	1,201*	—	75†	132† 872*	512† 2,266*	718† 425*	—	—	—	100†	230†	9†
Timber, Ochre, etc. . .	—	—	—	130	—	149	139	142	172	148	248	156	183	—	170	232	156	166
Silver, estimated quantity contained in lead ore.	Oz. 74,299	Oz. 125,090	Oz. 122,321	Oz. 147,516	Oz. 166,170	Oz. 173,718	Oz. 172,839	Oz. 172,528	Oz. 176,631	Oz. 145,483	Oz. 163,068	Oz. 161,612	Oz. 183,624	Oz. 170,106	Oz. 186,019	Oz. 110,496	Oz. 100,476	Oz. 69,667

* Hematite.

† Sphatose iron ore.

ISLE OF MAN MINING STATISTICS.—Continued.

TABLE showing TOTAL OUTPUT OF MANX MINES.

Year	1881	1882	1883	1884	1885	1886	1887	1888	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899	1900.
Lead ore (containing silver, as below).	Tons. 5,675	Tons. 5,494	Tons. 5,828	Tons. 6,007	Tons. 6,908	Tons. 6,257	Tons. 6,560	Tons. 6,356	Tons. 6,433	Tons. 6,141	Tons. 6,682	Tons. 6,608	Tons. 6,427	Tons. 5,624	Tons. 5,237	Tons. 4,563	Tons. 4,273	Tons. 2,948	Tons. 3,924	Tons. 3,843
Zinc ore - -	7,547	7,756	4,880	5,635	5,510	4,795	4,964	5,390	4,596	4,288	2,561	2,390	2,628	2,579	1,535	1,489	2,009	2,135	2,002	2,114
Copper ore - -	60	44	578	-	226	-	-	46	-	7	-	4	-	-	-	-	-	-	-	-
Iron ore - -	130†	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Umber, Ochre, etc.	207	171	183	-	-	-	-	-	-	No Returns.	-	-	-	-	-	-	-	-	-	-
Silver, estimated quantity contained in lead	Oz. 84,865	Oz. 129,769	Oz. 125,940	Oz. 123,251	Oz. 122,315	Oz. 135,456	Oz. 134,353	Oz. 128,083	Oz. 130,304	Oz. 129,124	Oz. 125,850	Oz. 124,949	Oz. 122,019	Oz. 111,325	Oz. 120,802	Oz. 107,643	Oz. 91,710	Oz. 76,419	Oz. 72,531	Oz. 66,067

MINING DETAILS.

List of Mines and Mining Trials in their order as described in the following pages. The names of the more important are printed in small capitals.

Foxdale Group.

BECKWITH'S VEIN.	EAST OR CENTRAL FOXDALE
Cross's Vein.	MINE.
Dixon's Vein.	Ellerslie, Glen Darragh, Bishops
OLD FOXDALE.	Barony, or Great East Foxdale
Magee's Mine.	Mine.
Old Flappy Vein.	CORNELLY OR TOWNSEND MINE.
Hodgson's or Faragher's Mine.	Ballanicholas Mine.
	Garth Trial.

Laxey Group.

GREAT LAXEY MINE.	SNAEFELL MINE.
NORTH LAXEY AND GLENCHERRY	Block Eary Trial.
MINES.	Glen Roy Mine.
East Laxey Trial.	Dhoon or Rhennie Laxey Mine.
East Snaefell Trial.	

Southern Group.

BRADDA OR SOUTH MANX MINES.	Iron Spout Trial.
BALLACORKISH, RUSHEN, OR	Glenchass Mine.
SOUTH FOXDALE MINES.	West Bradda Trial.
Ballasherlocke or Bellabbey and	Castletown Harbour Vein.
Falcon Cliff Mine.	Langness Copper Mines.

Northern Hematite Group.

MAUGHOLD HEAD, GLEBE VEIN,	BALLAJORA (BALLAGORRA) AND
AND DRYNANE MINES.	MARBRICK (MAGHER-E-BRECK)
	MINES.
	Ballasaig and other Trials.

Miscellaneous Trials.

Abbey Lands Mine.	Glen Rushen and Niarbyl Mine.
Ballaglass and Ballaskeg, or Great	Ingebreck Mine.
Mona Mine.	Kerroomoar Mine.
Barony Mine.	Kirk Michael Mine.
Baldwin Mine.	Laurel Bank and Wheat Michael
East Baldwin or Ohio Mine.	Mine.
Douglas Head Mine.	Maughold Head Copper Mine.
Ellan Vannin or Cartwright's Glen	Montpellier Mine.
Mine.	Mount Dalby Mine.
Glen Auldyn Mine.	Onchan or Douglas Bay Mine.
Glen Crammag Mine.	Pen y Phot Mine.
Glenfaba Mine.	Ramsey or Northern Mine.
Glen Meay, or North Foxdale,	
Mine.	

Notes on other vein-products.

Gold.	Plumbago.
Molybdenite.	

FOXDALE GROUP.

The Mines of the Central or Foxdale Area.

HISTORICAL AND GENERAL NOTES.

From both the geological and economic points of view the Foxdale Mines stand pre-eminent in the Isle of Man; during the latter half of the past century they have indeed attained to the first rank among the mines of the United Kingdom for productiveness, as well as for management, which has enabled them to survive successfully the vicissitudes in the market value of their product that have extinguished the industry in many mining districts. They are situated in the interior of the southern part of the Island, close to the head-waters of the Foxdale River. The and-west lode which they explore traverses the northern slopes of Barrule and Granite Mountain (formerly known as Slieau ny Clough) present workings being confined to the portion intersecting the village of Foxdale, at an elevation of from 400 to 450 feet above sea-level.

The date of the first discovery of ore in this locality is not known, but was at any rate before the early part of the 18th century, as in a report to Lord Derby in 1724 the governor of the Island mentions that "Foxdale hath from the first been worked with the least success . . . I have been forced to give it up, for the longer we work it the worser it grows."

Since the surrounding ground is more or less drift-covered, it may be presumed that the lode was first recognised in the bed of the Foxdale River, which crosses its richest portion. Old workings may still be seen in the vicinity of the stream; and it was probably these to which Foxdale is referred in 1798 as having produced rich and abundant ore,² and which Woods noticed early in the next century, in a deserted condition, the rubbish from the shafts consisting almost wholly of fragments of slate, with pieces of brown blende, a little lead glance and some sparry iron ore. ("Account of . . . the Isle of Man," 1811, p. 12.) Berge found the mines inactive (in 1811?); he mentions that a "small granite" had been found in one of the shafts, and that a productive and south cross-vein (see p. 510) had been discovered, with rich ore at its junction with the main vein. He was informed that the granite was found in a shaft 40 yards deep, where it "formed the north side of the vein, the galena adhering to it, while the south side was a stratified rock." Macculloch, a few years later, likewise found the workings deserted and inaccessible.⁴

Some information regarding these old workings has been obtained from documents preserved in the Office of Woods and Forests. In a schedule of the property purchased by the Crown from the Duke of Atholl in 1827-1828, we find under the heading of Lead-mines "*New Foxdale*," "*Foxdale*," and "*Flappy Vein*" (the cross-course mentioned by Berger) as three distinct mines; and it is mentioned that these are subject to be granted by the Duke to Michael Knott for a term of 31 years, ending on November, 1823. There is also in the same office an old plan and report prepared by J. A. Twigg in 1826, the former lettered, "Section of the Foxdale Mine, showing the course of the levels (driven near the vein) and view of the shafts at present sunk, and also some trials made upon the vein at the Surface." This plan shows the Engine Shaft 38 fathoms deep, with two levels west and five levels east from it; the lowest level was that at 15 fathoms, which went 160 fathoms east and was reached.

¹ Knowsley (Loose) Papers quoted by A. W. Moore in "History of the Isle of Man," vol. ii. p. 964.

² "Tour through the Isle of Man," p. 213.

³ Trans. Geol. Soc., vol. ii. (1814), p. 37 and p. 52.

⁴ "Western Isles," vol. ii., p. 577 (1819).

three air-shafts E. of Engine Shaft, and by one W. of it; and still farther E. were two more sinkings, to a depth of 15 fathoms, with short drivings. The ground-plan indicates the main lode, with a "south string" and "north string" [$\frac{1}{2}$ = Magee's Lode, see p. 510], just east of Engine Shaft: and a "strong vein" [$\frac{1}{2}$ = Flappy Vein] going off nearly N.-S. on the west of Engine Shaft; and also an E.-W. vein joining the "main vein" 33 fathoms west of that shaft, on which is the note "This vein contains manganese and other minerals not congenial to lead." It shows, moreover, the position of "shaft sunk by the old men," and "old workings wrought 40 years ago."

Soon after Mr. Knott obtained his lease he appears to have sold his interest to a company, who took up the working; and thenceforward, on one part or another of the vein, mining has gone on continuously up to the present day. The following account of the progress of the mine up to 1848 is given by Cumming:—

"The chief workings at that time [*i.e.*, circa 1823] were upon what is generally termed the Foxdale vein, to the northward of the great granitic boss, crossed by elvans striking out from the nucleus of the granite. Very little except horse and water power had been employed, though there were at that time two small steam-engines also at work, and the depth reached was never more than 40 fathoms. The great workings are now carried on [circa 1848] at the eastern and western extremities of the district, at Cornelly or Jones vein [see p. 516] in the neighbourhood of Kenna, and at the Beckwith vein in Glen Rushen. The Cronck Vane¹ mine, more in the centre of the district, on the brow of the hill betwixt Shieauwhallin and South Barrule, a few years ago was worked with very great results. The miners appear to have fallen in with one of those great sops or masses of ore which I have noticed in the body of this work as generally characteristic of limestone districts, but which appears as a peculiar feature of this schistose country also."

"At the time of my visit, in company with Professor Ansted, three years ago, the depth attained into the body of ore was 88 fathoms, the width of the vein or mass at its centre being 24 feet, thinning off to the E. and W. to about 4 feet. The length of this body of productive ore was 14 fathoms. The vein had generally a southerly dip, the walls being very clean, and presenting in several places extensive appearances of slickenside. There is very little gossan upon these veins, and not in general any indication of their presence till the workman comes directly upon the body of lead. The prediction of Professor Ansted at that time, respecting the duration of the working at the Cronck Vane Mine, seems to have been fully verified, as I found on my last visit to the place the works abandoned."

"The number of men and boys employed at the mines of this company in different parts of the district is generally about 350, and the average raising of ore for the last ten years has been about 2,400 tons per annum. The product gives about 70 per cent. for lead and 9 ozs. silver per ton."

Since the above was written, the operations on the eastern and western extremities of the Foxdale lode and on the Cornelly (afterwards known as Townsend) vein have gradually been suspended; and for many years past, work has been confined to deep mining on the site of the earliest workings close to Foxdale village. An admirable record of the later history of the mines of the district is contained in the series of reports made annually between the years 1857 and 1888 by Mr. (Sir) W. W. Smyth, as the result of his personal examination; these are preserved in manuscript at the London Office of Woods and Forests, and in the context will be largely drawn upon for information respecting workings which are now inaccessible.

In 1867, D. Forbes in describing³ the occurrence of Polytelite (Silber-

¹ This refers to Cross's Mine (Cross Vein of 6-inch Ordnance Map, Sh. 12), $\frac{1}{2}$ mile west of Doarlish Head.

² "Isle of Man," p. 309.

³ "Researches in British Mineralogy," Phil. Mag., 4th ser., vol. xxxiv pp. 350-4.

fahlerz) from the Foxdale mines, gave a short account of the character of the lode. He stated, on the authority of Mr. J. L. Thomas, that the polytelite occurred in the most easterly workings of the mine where the lode ran out of slate into granite, the minerals associated with it being galena, chalcopryite, iron-pyrites, zinc-blende, quartz, dolomite, chalybite and calcite. Mr. Forbes gave an analysis of the polytelite, showing it to contain 13·57 per cent. of silver. His remarks on the granite and on the reported occurrence of gold in the locality will be alluded to on a subsequent page (p. 549).

In 1880 Mr. (Sir) W. W. Smyth gave an account of the general features of the lode in a paper "On the occurrence of Feather Ore (Plumosite) in Foxdale Mine."¹ The following passages are quoted from this paper as supplying an excellent and authoritative description of the vein and its rare mineral, plumosite:—

"The masterly lode of Foxdale has been worked for some four miles, not quite continuously, on its east and west course, and to an extreme depth nearly approaching 200 fathoms" [since carried to 290 fathoms, see seq.]. "It varies in character, and often within short distances, to as great an extent as perhaps any lode that could be cited; sometimes, as at Beckwiths, a body of more or less ore material of 5 or 6 fathoms in width, in other parts exhibiting powerful ribs of solid galena with several tons of ore to the running fathom, again parting into parallel branches of an ordinary lead ore on the south wall, and others of a highly argentiferous variety affecting the north side, and often with from 2 to 6 fathoms of lode material between them. Between the courses and shoots of ore is encountered (and sometimes unfortunately for very long distances) a quantity of unproductive ground in which detrital killas, or granite, and ribs of chalybite (carbonate of iron), and singular veins and seams of an indurated black clay, form the chief constituents. This latter material, cutting sharply against some of the other lighter coloured substances, gives rise to appearances very instructive as regards successive openings and fillings of parts of the lode, and reminds one of the so-called *glauk*, which plays a similar part in the small but rich veins of tellurium and gold at Nagyag in Transylvania."

"Furthermore, the variation in appearance is added to by the fact that whilst the country rock has mostly been killas, the Old Foxdale Mine encountered granite at a medium depth—in some places only on one wall, and is now opening in many successive levels in a solid mass of that rock. No sudden alteration has been produced by the change of 'country'; but fluor spar is abundant in some of the western drivings, and in the deeper levels the main or south part of the lode appears to be more frequently than elsewhere a matrix of grey quartz. In these deeper levels a new and unusual feature has been the emanation of a gas, probably carbonic acid, from the crevices of the south wall of the lode, which has the effect of instantly quenching the flame of the candle, and at times had interfered with the work for days together."

"The chief engine shaft is Bawdens, and to the west of this, 10 to 20 fathoms, about the 100-fathom level, in a series of 'pitches' extending up to the 86, soon above which the killas comes in as 'country,' is the part of the mine in which the Plumosite has been found. Its *habitat* appears to be on the north side of the south part of the great lode. In other portions of the mine, about the 'old shaft' further east than the above, the well known antimonial ore of copper, called fahlerz or tetrahedrite, has been met with in spots and branches, notably at the 100 and 115-fathom levels; and the frequent tendency of this mineral to contain a large percentage of silver has no doubt had something to do with the unusual value for silver of the galena of some of the northern parts of the lode. These have in fact assayed at times from 100 to above 200 oz. of silver to the ton of lead, and have thus in many places admitted of being worked in thin strings, and in hard ground, where common lead-ore would not have paid to work. It might have been expected that the two antimonial minerals, the fahlerz and the plumosite,

¹ Trans. Roy. Geol. Soc. of Cornwall, vol. x., pp. 82-89.

would stand in some relation to each other. It is true they both occur at nearly the same level; but where the latter has been found there is no trace of the former."

"The plumosite is associated with a fine-grained galena, and a vuggy or cellular quartz, with many transparent crystals; it occupies these vugs, seldom filling them up entirely, but usually attached by one portion, whilst the remainder floats loosely. Its appearance is much like that of a piece of dark cotton wool, sometimes like a little wreath of smoke. . . . A closer examination will reveal multitudes of the finest spiculae, bright grey metallic-lustred hairs confusedly flung together, and sometimes so felted into one plane, the prisms crossing in different directions, as to look like a bit of rag or woven cloth. The colour, however, is always grey, and hence differs at once from the *Zundererz* or *Tinder ore* of the German mines, in which a notable proportion of silver, about 2.56 per cent., is revealed by the reddish colour due to an admixture of the mineral, Ruby silver ore. One or two of the specimens had a slight touch of that dull red colour which characterises the *Zundererz*; but in view of the minute quantity of the mineral it is difficult to decide whether the redness may be due to one of the 'ruby silvers' or to kermesite."

"Under the microscope the prisms come out distinctly; but it is difficult to be satisfied about their terminal faces. Other very curious features are now discernible; the hairlike prisms often affect curvilinear forms; arcs of circles and parabolas are not infrequent, and in some cases a coil of the microscopic hairs forms a perfect ring of very uniform thickness. The long crystals are flexible and elastic, and those which are anchored at one end will be seen to wave to and fro in a current of air. Some of these are adorned with minute bright crystals set at intervals upon them like beads upon a string. These latter appear to be cubical, and may probably be pyrites. . . . I cannot but regard it as a singular circumstance, under the data which we at present possess, that this new occurrence of plumosite should be connected exclusively with galena, quartz, and their usual associates. . . . The plumosite is, in point of date of deposition, the last mineral which has been formed in the little caverns of the lode, and its delicate fibres and webs seem to indicate, whatever process we may call in to explain their origin, a period of quiet and undisturbed action."¹

The emanation of carbonic acid gas from the lode, referred to by Smyth in the above account, was more fully described by Dr. C. Le Neve Foster in 1883,² who noticed the phenomenon in a cross-cut in granite, 14 fathoms south, from the 185 fathom level of the mine. Dr. Foster mentions in this paper that there had been a similar issue for a fortnight from a vug in the sole of the 80 fathom level of the Townshend (Cornelly) Mine three years previously, and that small escapes of the same gas had been reported from 'locks' in the Great Laxey Mine.

The further literature relating to the Foxdale mines includes a short general description of the lode in 1890 by Prof. W. Boyd Dawkins³; and the brief accounts to be found in most of the larger British text-books on Ore-deposits; e.g., J. A. Phillips' "Treatise on Ore Deposits," pp. 304-6 (2nd ed., London, 1896); C. Le Neve Foster's "Text-book of Ore and Stone Mining," pp. 335-8 (Lond., 1894).

While this memoir was in the press a short note on the mines by Capt. W. H. Kitto of Foxdale, read in 1892 before the Isle of Man Nat. Hist. and Antiq. Society, has been published (Yn Lioar Manninagh, vol. ii., 1901, p. 32). The following is Capt. Kitto's description of the lodes:—"There are several lodes in Old Foxdale, but the two principal bearing ones called the North and South, are very dissimilar—the former hard, with all its ore highly charged with silver, ranging from 50 to 400 ounces per ton, and

¹ Italics not in the original.

² Trans. Roy. Geol. Soc. of Cornwall, vol. x., pp. 175-6.

³ "On the clay slates and phyllites of the South of the Isle of Man, and a section of the Foxdale Mine." Trans. Manch. Geol. Soc., vol. xx., pp. 53-56.

at times having small quantities of Tetrahedrite or Fahlerz, an ore of copper and antimony averaging from 3,000 to 4,000 ounces of silver, whilst the South, or soft doukey lode, by its side yields comparatively little silver, but a greater quantity of lead ore."

With regard to the occurrence of Plumosite in the mine, Capt. Kitto gives the following additional information:—"Plumosite was first discovered in the western part of these mines at the 86 fathom level. It is associated with fine-grained galena, and a vuggy quartz, with transparent crystals; Recently we have discovered it in the eastern part of the mine, about 60 fathoms deeper, in grey quartz and killas, with both sides of the lode composed of granite. We have not found it in large quantities, and never entirely in granite, but always in the locality of lead rich in silver." (Op. cit. p. 33.)

The annual output of ore from the mines since 1845 has been published in "Mineral Statistics" and other official records, and from these sources the Table given on p. 512 has been compiled. The periodical reports of the managers of the mines, giving full details of the progress of the workings, have for some years past been reproduced *in extenso* in the local weekly newspapers published in Douglas. Files of these newspapers may be consulted in the Douglas Free Library.

DESCRIPTION OF THE WORKINGS.

The main Foxdale lode has been worked almost continuously, by a string of shafts extending from Glen Rushen on the west to a little to the eastward of Foxdale village on the east, a distance of about 2½ miles, with outworkings, on a supposed prolongation of one of its branches at Eairy ½ mile still farther eastward. Its leading characteristics have been given in the preceding general description and in the passages quoted from Sir W. W. Smyth's account of the mines. It has a persistent southerly underlie, and in the central portion of its course, where best defined, strikes in an average direction of E. 3°-5° N. to W. 3°-5° S. Both eastward and westward it splits into branches, and is lost in confused and broken ground. In spite of repeated searches (some account of which is given on pp. 546 and 548) it has not been traced west of the stream in Glen Rushen, and the most westerly working to yield a profitable quantity of ore is the Beckwith Mine, 400 yards east of that stream, at an altitude of about 650 feet above ordnance datum.

The diagram overleaf, based on the plans in the possession of the Isle of Man (Foxdale) Mining Company, will serve to show the position and depth of the shafts on the main lode, and the lie of its principal branches and cross-courses (Fig. 110.)

Beckwith's Mine.

The following account of the discovery of the riches of this temporarily productive portion of the vein was given by the late Mr. W. Beckwith under the date April 9th, 1881, and printed in the prospectus of the "New Foxdale Mining Syndicate" (Garth Trial, see p. 515):—

"The Beckwith vein was discovered by the driver of a hay-cart crossing the west side of South Barrule, who found a solid lump of lead-ore in the wheel-track; this induced me to make a search in the neighbourhood, when I discovered ore among the roots of the heather, and immediately put two men to work who, on the following day opened up the ore, and about 650 tons were raised before sinking was commenced. The ultimate result of this discovery was about 50,000 tons of lead-ore which realised about three quarters of a million sterling." . . . "Like all veins in the Isle of Man this enormous yield was irregular in its deposit, from the surface down to the 70-fathom level the vein averaging from 10 to 15 feet wide and

producing fully 15 tons of lead-ore to the fathom. In the next 20 fathoms the vein grew poor, but on persevering with the sinking the ore was again cut into at the 90-fathom level, this new deposit being more productive than before, in places fully 26 feet wide and yielding 30 tons ore to the fathom. This great productiveness continued for another 50 fathoms down when the mine again became poor, evidently from the same causes that existed in the levels above."

In spite of its magnificent commencement, the deeper part of the mine and the lateral workings proved entirely unprofitable and it was abandoned about 1866, though an attempt was made 15 or 20 years later to form a company to restart it. The main or 'Beckwith's' shaft attained a depth of about 185 fathoms from the surface, intercepting the 'old day-level' at 15 fathoms and the 'new day-level' at about 35 fathoms, with levels at 15, 30, 45, 60, 75, 90, 102, 117, 132, and 147 fathoms below the new day-level. The ore-body seems to have been very limited in lateral extent throughout, lying chiefly to the eastward of the main shaft, having a general trend westward, and disappearing in depth below the 102 fathom level. The vein appears to be a southerly branch of the Foxdale Lode, and strikes S. 10° W., with a southerly underlie. A supposed north branch, 200 to 300 yards north of Beckwith's, striking approximately E.-W., has been recognised by the miners as the 'North Gill Lode,' and tested in several places, but without profitable result. These converging branches are supposed to fall together in the vicinity of Cross's Mine (see below). Besides these E.-W. veins, a productive cross-course striking nearly north and south (N. 3° W.), named 'Wardell's North Lode,' occurs at the Beckwith Mine, and was worked by N.-S. levels from that shaft, yielding ore chiefly between the 60 and 90 fathom levels. In view of the importance of determining the relative ages of these veins, I made special inquiry as to their intersection, and was informed by Captain J. Kitto that the N.-S. (Wardell's) lode was found to be shifted about 3 fathoms eastward on the south side by the E.-W. (Beckwith's) lode. Their relations are thus the same here as in the Laxey, Snaefell, and Ballacorkish mines where the N.-S. veins are displaced by later E.-W. 'slides' or faults; with this difference, however, that whereas the 'slides' of those mines are almost invariably barren, in this case the E.-W. vein constitutes the most productive part of the mine.

The 'country' rock of the mine is a highly sheared sericitic striped slate, which merges westward into the dark blue homogeneous 'Barrule Slate' (p. 53) of Dalby Mountain, and eastward into a belt of alternately slaty and gritty flags. The prevalent dip of these rocks is at a high angle towards N.N.W., but in the vicinity of the lode and between its two branches north-north-easterly dips occur in several places. In the spoil-heap were noticed fragments of one of the common basic ('older greenstone') dykes crushed into a schist, but no trace of the Foxdale granite or its elvans exists in this locality. The ground around the mine is more or less drift-covered (p. 458), and it is only in the glens that the rocks are well exposed.

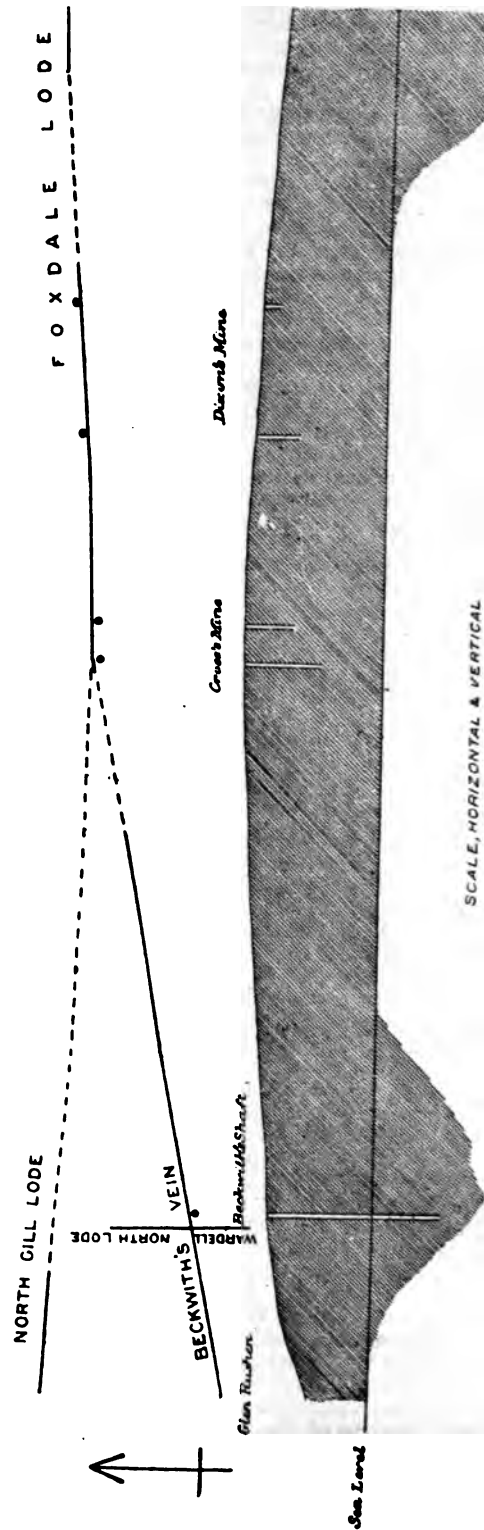
During the later stages of its activity the Beckwith mine was annually examined by Sir W. W. Smyth, and as it has now fallen to ruin and its workings are quite inaccessible, a few notes drawn from the MSS. reports of this authority may prove useful.

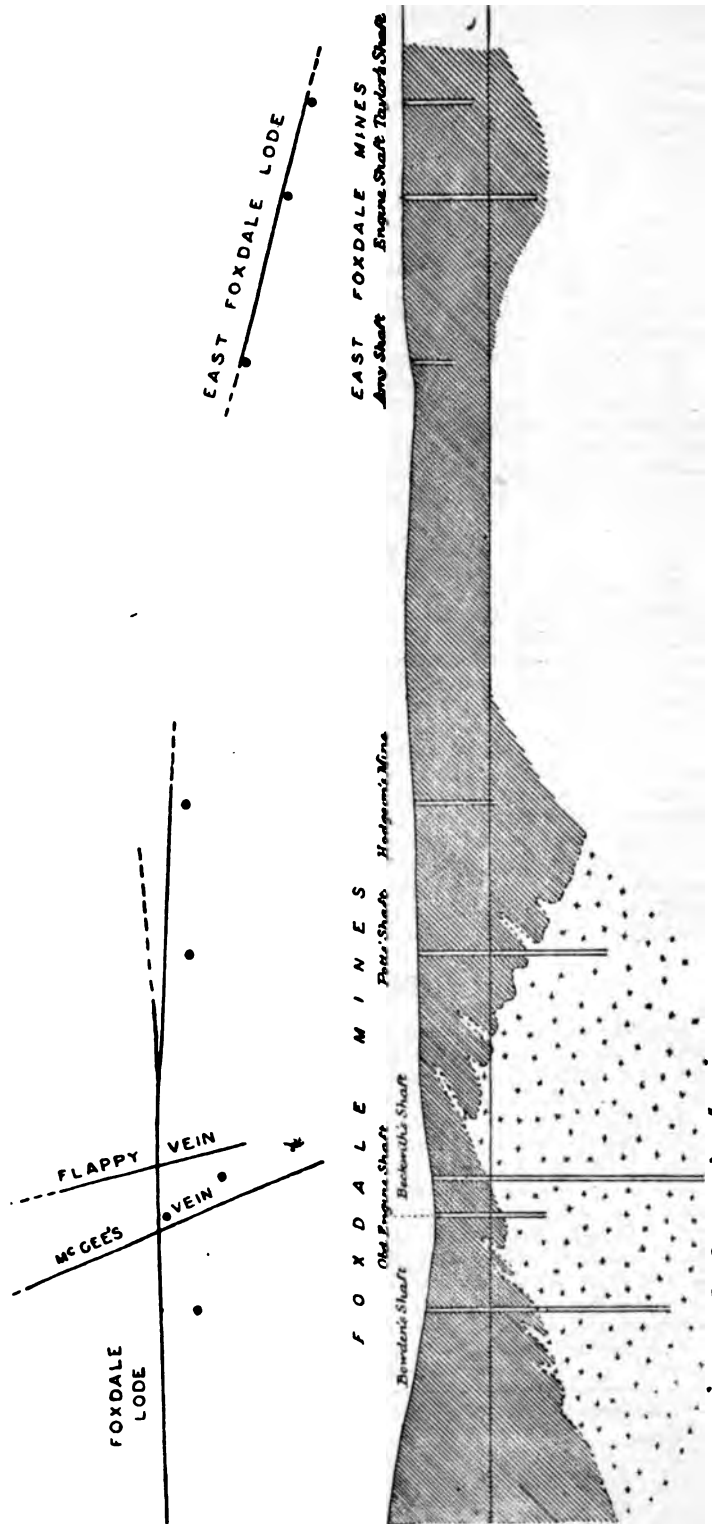
In the report for 1857 it is mentioned that down to below 90 fathoms the mine had been marvellously rich, but that the lower levels, at 117, 132, and 147 fathoms, had been driven on a lode showing hardly any trace of ore; and that a great drawback was found in the enormous amount of timber required and its rapid destruction by dry rot as well as by the heavy pressure of the strata. The N. and S. cross-vein had been opened to 160 fathoms S. of the shaft in the 75 fathom level, and a course of ore got in the same vein in the 60 fathom level N. In 1858 reference is made to a trial known as WEST BECKWITH'S at the western part of the Foxdale sett, where a shaft had been sunk 13 fathoms on a large lode filled with black clay-slate, but without ore. In 1859 it is noted that in the principal mine the total poverty of the lower levels had been a little relieved by

FIG. 110. *Diagrammatic plan and section of the Foxdale Lode.*

Manx Slates shown by oblique shading; Foxdale Granite and elvans by small crosses.

PLAN & SECTION OF THE FOXDALE LODE.





some small sprigs of galena at the 132 level in the west cross-cut, and that the 117 level had some very good ore on the N. part of the lode. On the "Wardell's" cross-course the 75 level was out 200 fathoms S., while the 60 and 75 N., both poor at the end, had passed through "a long run of tolerably good ground which will yield material for stoping." At West Beckwith's a level had been driven E. for 50 fathoms "in black shale with a little quartz," and doubt was expressed whether it was in the lode at all. In 1862 it is stated that "great lengths of gallery have been opened beneath the formerly rich parts of the lode without finding any noticeable ore"; and detailed accounts of the 117, 132 and 145 fathom levels are given, showing a total length of unproductive driving of "about 317 fathoms." The reports for the ensuing years record the gradual cessation of all work except that of driving the adit eastward, according to covenant, to connect with Cross's Mine, 1,200 yards E. of Beckwith's. In 1877 the inspection of this adit is described; it was reached by descending the main shaft to 40 fathoms, and followed for 345 fathoms, to the end, which was in very confused ground "where the two lodes, the main one and the North Gill are closing together"; it was now within 50 fathoms of the old workings at Cross's Mine, and was barren of ore, nor was any seen in the numerous cross-cuts. This level is also referred to in the two following years, after which the mine is not again mentioned.

Cross's Mine.

This mine, the position of which has just been indicated, lies at an elevation of above 830 feet above O.D. This is evidently the 'Cronk Vane mine' described by Cumming in the passage above quoted (p. 501). Its history appears to have been a repetition of that of Beckwith's Mine on a smaller scale—a good but limited ore-body having been met with in the upper workings; and poverty below. It does not seem to have been worked since its abandonment at the date noted by Cumming. The mine consisted of two shafts 80 yards apart, viz., 'Engine Shaft' on the west and 'Whim Shaft' on the east; with levels at 20, 30, 40, 50, 65 and 80 fathoms. The ore-body described by Cumming lay mainly between the two shafts, and was lost below the 65 fathom level, and also in the drivings east and west of the mine. The longest or pioneer levels were the 80 fathoms, which went 79 fathoms west from 'Engine Shaft,' and the 50 fathoms, which was driven 95 fathoms east of 'Whim Shaft' and ended in barren ground about 50 fathoms short of the most westerly driving from Dixon's Mine.¹

Dixon's Mine.

This mine, lying to the east of Cross's at a distance of only 400 or 500 yards, was worked by two shafts 280 yards apart, with levels at 17, 32, and 47 fathoms in the 'Engine (western) Shaft,' and at 17 fathoms in the 'East Shaft.'² The day-level was reached by a cross-cut from the little valley north of the mine. As in the mine last described, the workings were wholly in slate; very little ore appears to have been found. Smyth mentions it in his report for 1857 as having been sunk to the 47 fathom level, but with nothing of promise in sight; and in the following year describes it as a "great disappointment," some productive ribs at the 17 fathom level having gone out in the 32, and on the south side there was similar deterioration below the adit level. In 1865 we learn on the same authority that after being for many years abandoned a shaft and adit were reopened. In 1867 the adit had been cleared for no less than 200 fathoms, and the 17 fathom level opened, with a little lead westward, but on the east for scores of fathoms without showing a speck of ore; from the 34 fathom level a cross-cut had been driven out

¹ Information from mining plans in the office of the Foxdale Company.

² *Ibid.*

in which it was difficult to recognise the limits of the lode; and only a few tons of ore in all had been raised from this new undertaking. In 1868 it is noted that only a cross-cut at the 44 level was driving; and this is the last mention of the mine in the reports.

Foxdale (Old Foxdale) and associated Mines.¹

In following the lode eastward from Dixon's we descend into the Foxdale valley by a steep slope on which there have been a few shallow unproductive trials in the slates. The Foxdale Mines, from which by far the greater proportion of the mineral produce of the lode has been obtained, lie at the foot of this slope at altitudes of between 400 and 450 feet above sea-level. The principal shafts now in operation are—Bawden's the most westerly, with the bottom level at 260 fathoms; Beckwith's, with the bottom at 290 fathoms²; and Potts, the most easterly, with the bottom at 200 fathoms. The distance in a straight line between the first and last-mentioned is 750 yards, and the extreme length of the underground workings from end to end in 1897, was 1,510 yards; the pioneer level westward being the 170 fathoms, which went 320 fathoms west of Bawden's and approached within about 175 fathoms of the overhead position of the east shaft at Dixon's Mine; and the pioneer east, the 127 level, going 435 fathoms east of Bawden's. The above-mentioned shafts are sunk vertically on the southern side of the outcrop of the lode, and intercept it on the underlie. They commence in slate, but pass, at varying depths, into granite, as shown in the section (Fig. 110, p. 507), their lower workings being entirely in the igneous rock.

In the higher part of the mine the slate is traversed by elvans springing from the granite, which render the shelving upper surface of the intrusion ragged and uneven, just as it is seen to be at its outcrop on the hill-top south of the mines. Unfortunately the old upper levels which traversed the junction of the intrusive rock with the slate are now mostly inaccessible, and it is only at a few points that the contact can be studied. A few details respecting them may be gleaned, however, from Smyth's reports, quoted in the context. The junction was seen by the writer in 1896, in a cross-cut in the 115 fathom level, at the eastern end of the mine, and there showed distinct evidence of faulting, the granite being separated from the slate by a 'dowky' slightly slickensided vein an inch or two wide; but the vertical displacement did not appear to be great. As previously mentioned the lode, of which this vein seemed to form one of the 'branches,' is rarely a simple fissure but a belt of disturbed 'country,' with more or less parallel fractures showing nearly horizontal slickensides and containing brecciated rock, with vein-stuff and ore generally in ribs but occasionally also brecciated. The granite included in and adjacent to the lode has undergone partial decomposition, and it softens and 'bursts' on exposure to air in the workings; while the same rock exposed in cross-cuts outside the lode remains solid and very little altered. The rock thus affected is rendered somewhat 'platy' by numerous joints parallel to the vein, some of which exhibit traces of movement; and the miners appear to regard all material of this character as part of the 'lode,' ribs of ore being likely to occur anywhere within it. The 'bursting' of the rock-faces in the workings is probably due to the felspars having been decomposed while under restraint, rapid expansion taking place as soon as relief is obtained.

The ore-bodies have a general trend downward towards the west. The chief minerals associated with the galena in the vein-stuff have been enumerated in the passages already quoted. The western portion of the

¹ Our thanks are due to Capt. W. H. Kitto and Capt. Lean for their courtesy in affording us facilities for studying the plans and underground workings of these mines and the plans of several abandoned mines in the neighbourhood; and to Capt. J. Kitto, sen., for information in respect to many of the older workings in this and other parts of the Island.

² Beckwith's Shaft has now a level at 305 fathoms, and is being sunk for a 320-fathom level. (August, 1902.)

mines is on the whole characterised by the presence of large bodies of coarsely crystalline galena poor in silver; and the eastern, by small quantities of fine-grained ore rich in silver. With regard to the occasional presence of the rarer minerals, *silberfahlerz* and *plumosite*, we learn from Sir W. W. Smyth's and Capt. Kitto's notes that these minerals are limited to that part of the vein which lies in the vicinity of the junction of the vein with the granite.

The seam of "indurated black clay" mentioned by Sir W. W. Smyth is a peculiar feature of the lode; it is rarely absent, serving the miners as an indicator where the vein is pinched or unproductive. It varies from a thin film to a thickness of 2 or 3 inches, and widens out into a 'dowky' mass in the vicinity of the ore-bodies; and in such places is reported sometimes to contain 'stones' of ore. It has probably been brought down by percolating waters from the overlying slate during one of the later erosion-movements along the fissure, perhaps at the same time as the detritus observed by Smyth in the 170-fathom level east, which exhibited the peculiarity of fragments of *killas* or clay-slate in the breccia [of the lode] unexpected so deep in the granite." (MSS. Report for 1894. See description of the 155-fathom level quoted in the context.)

Between Beckwith's and Pott's shafts the lode in going eastward divides into two branches, and to the eastward of the Pott's shaft becomes obscure and difficult to follow. The abandoned workings farther eastward are subsequently to be described.

Regarding the cross-veins known as *MAGEE'S VEIN* and *FLAPPY VEIN*, which, as shown in Fig. 110, are about 140 yards apart and strike across the main Foxdale lode in the neighbourhood of Beckwith's shaft, no definite information is now procurable, as the places where they intersect the main vein in the upper levels are inaccessible, while in the lower levels they are not definitely recognisable. We may suppose that, like Wardell's North Lode at Beckwith's Mine (p. 502), they were formed at an earlier date than the E.-W. main vein, as otherwise some indication of displacement of the latter at the intersection would probably have been noticed. Both veins yielded lead-ore in limited quantities. *FLAPPY*, the more easterly of the two and the one referred to by Berger (p. 500), is shown on the mining plan as having a course of S. 22 deg. E., with a westerly dip. It was followed for 150 fathoms southward in a driving from the 20-fathom level E. of the Engine Shaft of Foxdale Mines, and had also three levels, viz., adit, 20 fathoms, from a shaft on the lode; and was further tested by work for 650 yards north of Foxdale. *MAGEE'S* strikes S. 30 deg. E., with a westerly dip, and therefore converges towards *Flappy*, with which it is supposed the miners to unite on the hillside south of Foxdale. It is no doubt the "strong vein" west of "Engine Shaft" shown on Twigg's plan of 1860 (p. 500). It was worked on a small scale as recently as 1878, by a shaft 300 yards S. of Foxdale, as described by Smyth in the reports quoted below. The vein is supposed to be visible at the surface, in the granite quarry at the margin of the granite mentioned in a previous chapter (p. 165).

The following information illustrating the geology of the main lode in the older parts of the Foxdale Mines is abstracted from the annual MSS. reports of Sir W. W. Smyth, whose interest in this mine was always keen. In his report for 1857, we learn respecting "Old Foxdale" that in the 50 fathom level a part of the lode adjoining a dyke of granite was unusually rich in silver (up to 300 oz. per ton of lead) and that to the west of the [Old Engine] a large quantity of sparry iron-ore formed the bulk of the lode. In 1860, the Engine Shaft is stated to be about 4 fathoms below the 86 fathoms, in a very hard close-grained granite, and the lode brecciated on a large scale, exhibiting no lead ore; while in the 72 level west there was an excellent lode, "the ore parts yielding silver in very variable proportions, averaging 70 oz. to the ton of lead." In 1861, the last-mentioned level is described, in which "a cross-cut south near the end has entered a white granitic porphyry, and found a small south vein separating the latter from the clay-slate;" and in the shaft, now at 96 fathoms, "all except the south side is in very hard granite; on that side a large amount of sparry carbonate

iron is visible, which I hope promises for the continued strength of the lode in descending." In the 72 fathom level east, some of the galena ran to the extent of 180 ounces per ton in silver. In 1862, the east and west driving of three levels—the 86, 72, and 60 fathoms—is described, "now against granite, and presently against slate"—"varying much in richness, but on the whole offering to view a noble lode of highly argentiferous lead ore." In 1865, the deepest level was the 100 fathom, which was 105 fathoms west from Engine Shaft in a fine lode 5 feet wide, between soft granite walls, and rich for lead ore, but was impoverished east of the shaft. In 1866, when the deepest level was still the 100 fathom, the report contains the following passage [regarding which we may note that the later workings have fully justified Smyth's judgment and confidence]:—"It becomes now an interesting question whether the vein will be as productive when entirely in the granite as when passing between alternations of that rock and slate. I myself see no *a priori* reason to doubt that it will be as good, and hence look forward with impatience to the driving of a deeper level." In 1867 we learn that the bottom or 115 fathom level west, all in granite, had a rib 2 to 8 inches wide of good lead ore, but not rich in silver; while specks and lumps of fahl-ore or tetrahedrite very rich in silver had been found in stopes on the 100 fathom east. [This concentration of the ores rich in silver in the northern side of the vein near the junction of the granite and slate deserves especial attention.] In 1868, it is noted that "this is the second year during which considerable quantities, amounting to 8 or 10 cwt. (in the rough) of highly argentiferous fahlerz have been raised from the mine." In 1872, the 72 fathom level west under the mountain [the pioneer level at that time] is described, in which a cross-cut north for 20 fathoms near the end was in hard white granite. The 115 fathom west showed in one place "ore of a gossany character with spiculæ of cerussite or white lead ore, rather a rare feature at such a depth." Bawden's Shaft, now 10 fathoms below the 127 fathom level, was sinking in hard granite, "the rock exceedingly obdurate, but showing a small vein of hard breccia with some steel-grained lead-ore." The 100 fathom level east was out 205 fathoms from "Old Shaft," and the lode in the end "full of clay slate." In 1873, it is mentioned in regard to the end of the 86 fathom level east that "here, too, the walls change again to soft clay slate." In 1880 "the 140 fathom has for a very long way been entirely sterile—large and conglomeratic in the end, with embedded stones of dark granite"; and the west ends of the 170, 155, and 140, all somewhat alike, show "a great lode of disintegrated white granite seamed by small veins of black indurated clay, and showing only specks of lead and zinc ore with a little quartz and traces of fluor." In 1881, the 84 fathom level east is described as containing "the finest regular rib of ore ground which I have seen in the mine, the lode very uniform and averaging 20 to 24 inches wide of very compact galena of medium richness and silver." In 1882, Beckwith's Shaft had been sunk 40 fathoms "in rather hard schist." In 1883, the 127 E. at 190 fathoms from Old Shaft had a lode 3 feet wide, "with a copper-bearing branch [unusual in this mine], and strings of dark quartz containing steel-grained ore, and a little of the silvery fahl-ore." The adit driven westward to prove the ground under the mountain was over 150 fathoms long, in 'dook' or argillaceous vein-stuff but uniformly poor. In 1885, it is noted that all the workings at less than 100 fathoms were stopped; the 140 E. showed a good deal of white barytes and chalybite, with several strings 6 to 10 inches apart of good silvery ore; the 200 W. had laid open "a magnificent lode of ordinary galena," "reminding the observer of the richest of the Spanish mines"; and surprise is expressed that the new shaft though in solid granite had required timber for half its length. In 1886, when some of the eastward deep drivings were getting out of the granite, we learn that the 127 level showed bunches and strings of dark ore, richer than the average in silver, and "very much like Mexican and Hungarian ores"; in the 140, E. end, there was "schistose rock on both sides, taking the place of granite"; the 170, cross-cut S. close to end, "again revealed a wide body of schistose rock of white hue, which towards

the end lay almost flat upon granite" [possibly a highly sheared aplite dyke, see p. 165]; while the 185 level had granite for the 'country' on both sides. In 1887, the 155 level E. "presented the curious feature of contorted blue shiny slate, forming the body of the lode against a granite foot-wall, but without ore"; the 215 E. of Bawden's Shaft had "a marvellous lode" 6 to 9 feet wide, capable in places of yielding 8 to 10 tons ore per fathom. The last of these reports is for the year 1888. It states that the deepest level was the 230 fathom; that the 170 E., in soft killas or slate rock, had a cross-cut a little way back from the end, driven N. for 4 fathoms in granite, sometimes very pink; and that in the 127 E. on the N. branch of the vein, here a curious jumble of pyrites, lead ore and chalybite, a parallel vein with highly argentiferous fine-grained steel ore had been found by cutting 4 fathoms still further N. through slaty rock.

TABLE SHOWING ANNUAL OUTPUT OF SILVER-LEAD ORE FROM THE
FOXDALE MINES BETWEEN 1845 AND 1900.

From Mineral Statistics in Mem. Geol. Survey, vol. ii. (for 1845 and 1847); Records of the School of Mines, vol. i., pt. 4 (for 1848 to 1852); Home Office, Mineral Statistics (1853 to 1900).

Year.	Lead-ore.	Silver contained in Lead-ore.	Estimated Value.	Year.	Lead-ore.	Silver contained in Lead-ore.	Estimated Value.
	Tons.	Ounces.	£		Tons.	Ounces.	£
1845	1,902	No data.	Value of Lead-ore not stated before 1874.	1873	1,433	57,727	—
1846	2,071	"		1874	1,673	67,868	31,562
1847	2,040	"		1875	1,722	73,564	37,804
1848	1,566	"		1876	1,607	65,183	33,284
1849	1,527	"		1877	1,727	87,700	32,314
1850	1,340	"		1878	1,959	53,453	29,733
1851	1,660	"		1879	2,766	55,319	37,363
1852	1,600	12,224		1880	3,486	49,799	42,993
1853	1,750	18,800		1881	3,419	69,080	39,145
1854	1,900	19,926		1882	3,211	48,807	36,356
1855	2,535	26,756		1883	3,700	48,100	35,100
1856	2,500	35,512		1884	4,020	51,525	33,500
1857	2,125	30,136		1885	4,670	59,851	42,400
1858	1,820	25,807		1886	4,013	51,435	43,000
1859	1,650	37,028		1887	4,322	55,396	41,500
1860	1,950	43,144		1888	4,009	59,397	44,600
1861	2,082	56,098		1889	4,185	62,010	44,400
1862	1,739	53,900		1890	4,160	61,640	44,500
1863	1,715	54,480		1891	4,700	69,641	45,200
1864	1,792	65,173		1892	4,650	73,550	40,250
1865	1,590	57,236		1893	4,650	73,550	35,400
1866	1,615	65,808		1894	4,800	85,522	34,430
1867	1,579	70,675		1895	4,600	60,359	39,200
1868	1,774	72,427		1896	4,250	188,473	36,700
1869	1,700	69,959		1897	3,775	76,697	34,100
1870	1,800	81,880		1898	3,610	66,125	34,000
1871	1,670	75,032		1899	3,610	62,515	39,800
1872	1,734	86,050		1900	3,610	58,905	43,100

Respecting MAGEE'S MINE, Smyth notes in 1859 that it was "on a north and south lode, in which a winze is sinking below the 40 fathom level. The veins are here in the midst of solid granite—mere strings, and but little or

is raising from them." The mine is not mentioned again until 1868, when had three ends advancing, and was yielding some 10 to 13 tons of ore per month. In 1871, we learn that the 60 fathom level was driving south, and the 72 both north and south, and the shaft was being deepened; the lode, generally only a few inches wide and encased in very hard granite, had opened to 5 feet wide in one part below the 60, and also proved continuous beyond a dislocating cross-course. [The last-mentioned fact apparently furnishes another example of the displacement of N.-S. lodes by E.-W. faults, and lends strength to the supposition advanced above as to the relations of this vein to the main Foxdale lode.] In 1873 the mine had been deepened to 84 fathoms, but the vein was still the same small string, and work was soon afterwards abandoned.

Hodgson's, otherwise Faragher's or Louisa Mine.

This mine, the latest working of which took place over twenty-five years ago, lies immediately to the eastward of the present Foxdale Mines. The principal (Louisa) shaft is 260 yards east of Pott's Shaft, and one or two of the higher levels are connected with the corresponding levels of that mine, the two shafts having at one time been worked together, under the name of Faragher's Mine, on the south branch of the Foxdale Lode. The Louisa shaft was sunk to a depth of 82 fathoms, with levels at 10, 20, 38, 53, 67, and 82 fathoms, the pioneer eastward being the 20 fathom which was carried 110 fathoms east of the shaft. Two small pits, respectively 50 and 90 yards east of this shaft, descended only into the upper level of the mine.¹ None of these workings reached the granite, slate being the country-rock throughout the mine. A fair quantity of ore was obtained at an early period in its history, but the subsequent operations were unprofitable.

Sir W. W. Smyth's reports contain a few references to the latest working, from which the following details are taken. It was in operation in 1860 and 1861, but yielded no return. In 1863 Smyth notes that the 52 fathom level was driving east and west on a greatly improved lode, with an excellent rib of lead-ore. In 1865, the 67 fathom level had been opened east and west, with only an unsatisfactory quantity of ore. In 1870, the 67 and 82 fathom levels were equally poor at ends, but there were "stopes with a little good ore in the midst of soft killas rock." The latest reference to the mine is in 1874, when the 30 fathom east, having been cleared, showed a little ore here and there, but nothing regular; and in the 72 and 84 levels the vein was "too small."

To the eastward of this mine there is a belt of crushed sericitic slate, occupying the ground up to the depression half a mile distant in which the Santon River has its source. Numerous shallow trials have been made without success in this tract to find the prolongation of the lode. As suggested in a previous chapter (p. 166), there may possibly be extensive transverse faulting in this hollow, perhaps the continuation of the eastern boundary fault of the Peel Sandstone; and this may explain the isolation of the small outlier of granite $\frac{1}{4}$ mile south of Eairy (p. 166) and the shattered condition of the slates between this outlier and the main granite mass, a condition likely to render the ground unfavourable for the production of lode-fissures. At the hamlet of Eairy, immediately to the eastward of the hollow, however, some extensive mining work, known as the East Foxdale or Central Foxdale Mines, has been done on a vein supposed to represent the continuation of the south branch of the Foxdale lode. The identification is scarcely convincing, since the Eairy vein differs in many of its mineral characters, and in its more southerly strike, from any portion of the Foxdale lode above-described.

¹ Details from plans in Foxdale Co.'s Office.

East Foxdale, otherwise Central Foxdale Mine

The East Foxdale workings comprise the Amy Shaft a few yards of the bridge at Eairy; the Elizabeth, afterwards renamed Engine 350 yards farther eastward; and Taylor's Shaft, 200 yards east of the first-mentioned appears to have been only once in operation in the early days of the mine (see Smyth's report for 1876 quoted below). According to plans preserved in the Woods and Forests Office had a depth of a little over 40 fathoms, with short drivings at intervals of 40 fathoms. The other shafts have been reworked three times, after longer or shorter intervals of inactivity, working continuing up to 1889; by which time Engine Shaft attained a depth of 145 fathoms, and Taylor's Shaft 74 fathom levels at about every 10 fathoms down to 40 fathoms, and 40 fathoms below. Although in the aggregate a considerable quantity of lead-ore averaging well in silver (about 35 oz. per ton) was obtained from the mine (see Table p. 515) it was insufficient to pay working expenses. The chief ore-bodies were found to the east of Engine Shaft. The mine was complicated and difficult, two or three separate lodes or branches of the same lode being recognised. Geologically the most interesting feature of the mine is the occurrence of an intrusive dyke of olivine-dolerite (supposed to be of Tertiary age, see p. 327) in association with the ore. Similar dykes occur in connection with north and south metalliferous veins at Ballacorkish, Bradda, Glen Auldyn and other places in the district, or in any other lode with an approximately east and west bearing. The significant bearing of this matter on the origin and age of the ore-veins has been discussed in the introductory chapter of the present work. The mine-workings are now inaccessible, and the information which I was able to collect on the spot regarding the occurrence of the dyke was meagre and unsatisfactory; but for Sir W. W. Smyth's reports, quoted below, contain many valuable particulars on this point and prove that the lode in this portion of its course is older than the intrusion. There is a doubtful exposure of the dyke at the steep slope immediately E. of the bridge at Eairy (see p. 1). At the spoil-heaps of the old mine 400 yards farther east the rock is in abundance.

The mine was reopened, under the name of "East Foxdale," in 1860 and 1863, but beyond the statement that £11,000 were then expended without result, Smyth's reports contain no details of this working. In 1864 a new company commenced operations, and in Smyth's report for 1865 is read- "The old workings of the 30-fathom level and the newer ones of 60 and 75 fathom levels show a great deviation from the regular bearing of the Foxdale Lode, and the presence of dykes and masses of a trachytic rock rendered the mine a costly problem. In the following year a 100-fathom cross-cut from the 90 level showed "more or less confused appearance of vein-stuff," and in Taylor's shaft driving was going on in the middle of three which had been tested. In 1875 the name of the mine was changed to "Central Foxdale," and the report states that the Engine Shaft was sinking below 90 fathoms in killas, and the 90 level had been extended east about 40 fathoms from the shaft and, from the place where it was cut, is amid the black trap rock, in which mere strings of spar are seen. Where the grey killas or slate comes in a lode improves, and a few stones of ore have been met with"; the shaft was out 15 fathoms, in ground much disordered and not promising. At 60 fathoms east has been driven east beyond the confusion caused by the trachytic rock for the last fathom or two as if in a wide body-mass with occasional spots of lead ore, exhibiting as its most promising feature of chalybite or spathose iron-ore." In 1876 Smyth notes that he drove to the 40 fathom level in Amy's Shaft "to see the driving westward of the black trap rock alongside the vein on the north, and altogether unpromising appearance." In 1877 the various drivings are dis-

including the 90 east, in which an exceptional body of rich ore ground had been found; and the difficulty of becoming acquainted with "the ramifications of these disordered lodes" is commented on. In 1878 the "hard black stone" is mentioned as making its appearance in the 105 level west.

Up to this time Smyth seems to have entertained the miners' opinion that the dyke cut out the lode, and his report for 1880 is therefore especially important in showing that he found this opinion no longer tenable. The passage in question reads:—"At the 120, the deepest level, a careful examination shows that the 'black stone' or *dolerite* which it was feared might cut off the lode, is really intersected by it, and in the eastern drivings the lode, divided into two parts, exhibits a considerable improvement." [Italics not in original.] Similarly, in his report for 1882 he mentions that in the deeper level then driving, at 135 fathoms, where the lode was in places very wide, between walls of clay-slate, there had been "a somewhat alarming appearance" of *dolerite*, but that it "seems really not to have injured the lode." In the previous year he noticed that in the 105 level east, where the lode had split into two branches, the north branch had got into "the volcanic rock of a rather pale tint."

In 1883 the mine was again standing, but was resumed by a new company in the following year. In 1886 the report states that 25 to 30 tons of ore per month were being raised, and that the 145-fathom level (the deepest point attained in the mine), driving east on the south lode, had met with some 'greenstone' on the north wall. In 1888, in the last of his reports, Smyth mentions that he did not go below, but gives the information that "spots of copper, with lead and zinc" had been found in a driving at 135 fathoms on the south lode; and adds that "some stones of granite which have appeared in the bottom level form a reminder of the bottom levels of Old Foxdale and give encouragement to further sinking." Under the circumstances it may be doubted whether the "granite" referred to was anything more than one of the granitic elvans by which the slates in the vicinity of the mine are traversed (p. 167); at any rate no confirmatory evidence has been obtained for the presence of massive granite in the mine.

Output of Lead-ore from East or Central Foxdale Mine (from "Mineral Statistics").

Year.	Lead-ore.	Silver.	Year.	Lead-ore.	Silver.
	Tons.	Ounces.		Tons.	Ounces.
1872	50	819	1881	400	5,362
1873	135	2,200	1882	450	10,440
1874	58	968	1883	530	15,900
1875	20	280	1884	330	9,839
1876	70	591	1885	325	6,447
1877	198	1,184	1886	319	10,149
1878	360	6,074	1887	418	11,625
1879	360	4,337	1888	250	6,953
1880	250	5,032	1889	92	2,559

From the above descriptions it is evident that even if the Foxdale Lode be prolonged in these mines it has lost its definiteness of character and direction; and it is therefore not surprising to find that all efforts to follow it still farther to the eastward have, up to the present, proved ineffectual. Traces of these old trials break the surface in several places on the Lreem Lang ridge east of Fairy, while in the valley near GARTH, one mile east of the EAST FOXDALE mines, a more extensive trial known as the NEW FOXDALE MINE was made in 1884-7 with no success.

The prospectus of this trial stated that the vein to be tested was wide and contained carbonate of iron, barytes, quartz, pyrites, galenite, and blende. The principal working consisted of a cross-cut adit on the bank of the stream, driven about 30 fathoms to the lode; with a level for 30 fathoms westward on the lode; and three short cross-cut from the level; only "indications" of ore were obtained. The slate which forms the 'country' in this locality is traversed by a dyke of microgranite, which was cut in one of the workings (see p. 168).

Ellerslie, otherwise known as Bishops Barony, East Foxdale, or Darragh Mine.

This old mine is situated on the Bishops Barony on the south-west of the central valley of the Island, $\frac{1}{2}$ mile S. of Crosby, at the mouth of the little glen of the stream draining from Garth. It has been worked for lead and W. vein supposed to be connected with the Foxdale lode. The mine has been reopened at various times, but always without commercial success and is now in ruins. From Mr. A. W. Moore's researches it appears that the mine was commenced about 1825 by the orders of Bishop Murray, the site was fixed "by following the direction of that rich vein which has been wrought to such great advantage at Little Foxdale" (quoted from the "Manx Advertiser" newspaper). Cumming, in 1848, gave the following account¹:—"It appears to have been commenced on a very thin vein consisting of a narrow thread of ore in veinstone, the outcrop being at the surface in a small burn The vein which has been followed from its outcrop upwards of 300 fathoms, at a depth of 6 to 10 fathoms presents such a striking uniformity as greatly to discourage further work. At one or two points cross courses have been met with, but they do not affect the value of the vein."

By the later workings a shaft was carried down to 75 fathoms, where a small quantity of lead was obtained. In 1875 the mine, then recently reopened, was examined and reported on by Smyth, who described the lode as 75 fathoms deep, "and in this a lode varying generally from 3 to 6 feet in width opened occasionally, as in the present end E., the lode yielding promising ribs of ore."² In this report Smyth inclined to the opinion that the lode, from its "line of bearing and the character of the ores," might represent the prolongation of that of Foxdale; but in his report (for 1885) he concluded that the mine was tolerably certain to be a different lode from Foxdale. In 1878 he noted that some fine ore was being obtained from pitches in the back of the 70 fathom level.

In "Mineral Statistics," returns of lead-ore are given from "Glen Foxdale Mine" in 1875 and the three succeeding years, amounting in aggregate to 301 tons, and 8 tons in 1883 from "Glen Darragh Mine."

Cornelly or Townsend Mine.

This mine, abandoned since 1884, was worked on an east and west line parallel with that of Foxdale, about a mile farther north, on the north-east slope of Archallagan, at the head of a short deep glen—"Glion Darragh" of the 6-inch Ordnance map (Sheet 9), but now known to the country as Ballacurry Glen. The lode was of a curiously irregular character, not easy to follow. Cumming mentions the mine as in operation in 1874, but respecting these early workings, when it was known as the "Glen Darragh Mine," no detailed information has been obtained; the later workings, under the title of the "Townsend Mine," between 1874 and 1884, are described in Sir W. W. Smyth's reports (see below); and plans

¹ "Isle of Man," p. 310.

² MSS. in Woods and Forests Office.

preserved in the Woods and Forests Office and in the office of the Isle of Man Mining Company at Foxdale. From these plans it appears that at the cessation of the last workings, the mine consisted of two shafts 12 fathoms apart, with levels from the Engine Shaft (the deepest) at 20, 40, 50, 65, 80, 95, 110, 125, and 140 fathoms. The pioneer level was the 95 fathom, which was carried 360 yards east and 195 yards west of the shaft, with a cross-cut going 70 yards southward from it. The chief ore-bodies were found in the neighbourhood of the shafts. The lode was very steep, with a slight underlie southward in the upper 80 fathoms and in the opposite direction below that depth. It contained much chalcedony, and had been affected to even a greater degree than the Foxdale lode by recurring movements by which the vein-material as well as the country-rock had in places been fractured, rounded and afterwards re-cemented. Among the minerals noted by Sir W. W. Smyth² from this vein besides galena, chalybite, etc., are semi-opal or cacholong, hornblende ("mountain-leather"), a beautiful iridescent variety of galena, and a curious variety of zinc-blende in balls with a radiated structure. A considerable output of lead-ore was made from the mine, but not in quantity to pay the expense of working. As the returns were included with those of the Foxdale Mines, no statistics are available.

The chief geological interest of the mine lies in the fact that, as mentioned on p. 165, though nearly 1½ miles N. of the nearest outcrop of the granite, the shaft penetrated that rock beneath the slate at 300 to 400 feet below the surface. Judging from the material on the spoil-heaps, some part of the igneous rock reached in the mine possessed the massive boldly-crystalline character of the Foxdale intrusion, and was not like the micro-granite dykes which strike out from that mass. It is therefore probable that the granite represents a local protuberance on a deep-seated mass, and not merely a dyke. The rock seems to have occurred very irregularly in the workings, at first in detached strings and afterwards in a massive body; and the deeper levels both east and west were again in slate, though the cross-cut south was in granite. The evidence given below suggests that the intrusion formed a pipe-like mass inclining westward; the fine-grained material mentioned in the reports probably occurred around the margin, with the more coarsely crystalline rock described on p. 315 in the interior. The high degree of schistose and garnetiferous alteration in the slate-rock of this vicinity has been discussed in a previous chapter (pp. 111-2).

It is fortunate that Sir W. W. Smyth's reports contain descriptions of this interesting mine, as the workings are now inaccessible. The following passages have been selected from these reports as showing the general character of the lode and of the granitic intrusion.³ In his report for 1875 Smyth states:—"The shaft is again sinking [below the 60-fathom level] and a peculiar phenomenon which somewhat links this mine with Old Foxdale is that veins or tongues of granite intersect the schistose rock, whilst a great difference is in the hardness of the rock, which scarcely requires any timbering." In 1877 we learn that in the 80-fathom E. level (then the deepest) "the lode is generally 2 or 3 feet wide, but carrying narrow vugs or caverns of great length lined with beautiful crystals of galena, but not enough to make a rich lode." In 1878, "the last 6 fathoms of the shaft [above 95 fathoms?] were in hard grey granite; the 95-fathom level had been driven about 30 fathoms, and was productive nearly all the way through; the lode a very singular one, vuggy, sometimes fragmentary with sharp angular country stone; the ore attached very generally in single or groups of cubical crystals to thin plates of quartzey veinstone with brown spar; and the better parts giving about a ton to the fathom. . . . About the place where the east end [of the 80-fathom level east] was in 1877, granite had come in on the country and continues to the present

¹ For access to the later plans and much other information my thanks are due to Capt. W. H. Kitto, of Foxdale.

² In "List of Manx Minerals," *op. cit.*, pp. 143-147.

³ From MSS. in the Woods and Forests Office.

end [*i.e.*, for about 45 fathoms] where the lode is pinched to dimensions of 2 to 5 inches." It is also mentioned that a quantity of gas, probably carbon anhydride, had been given off for weeks together in this part of mine, a feature likewise observed in the Foxdale lode in granite (see p. 1). In 1879 it is noted :— "the Townsend mine is proving to be a remarkable place, as having a distinct character from either of the other mines in neighbourhood [*i.e.*, Foxdale and Central Foxdale], and as yielding large amount of lead ore very little intermingled with vein-stuff or for substances . . . The 95-fathom level west shows a small but ore-rib of 4 inches in mica-schist. A pitch above this level is in a wonderful g of parallel ribs and cavernous hollows studded with crystals of gale all sizes up to 6 inches across; the whole occupying 3 fathoms in w and having to be heavily timbered." The 65-fathom level east was driven "the country intersected being micaceous schist, which in a large part the deeper exploration is replaced by a granitello or unusually fine-grained granite." In 1881 the 95-fathom level east (which had commenced granite) was visited, and "at 150 fathoms from shaft I found that long distance the level had been in a dark hard schist with an utterly sterile lode. . . . The 110-fathom level west was in a granitoid rock, hard, with scarcely a vestige of a lode." In 1883 it is noted that the level was down below 140 fathoms, and that the 125-fathom level east had a poor quartzose lode of 3 feet, and a good rib, 4 to 6 inches wide, of beautifully iridescent lead-ore, while in the same level west the lode was a string an inch wide set in hard granite rock. The latest mention of the level is in the report for 1884, where we learn, respecting the deepest level,—"140-fathom level which is again in the slate-rock, exhibited at first, on east, the old 'Townsend' type of a hollow broken lode and with crystallisation of lead ore," but afterwards changed for the worse. The deepest level appears from this account to have been altogether in slate but we are informed by Captain Kitto that the shaft itself was in granite to the bottom, though the ends of all the pioneer levels were in slate.

Traces of old trials are seen on the north side of Coillingill near Croft 1 mile to the east of the above mine; and others, $1\frac{1}{2}$ miles to the west on the western slope of the lower part of Foxdale (see List, pp. 552). These are said to have been on supposed prolongations of the Corn lode; no further information has been obtained in regard to them.

Trials South of Foxdale.

On the southern side of the watershed, south of Foxdale South Barrule, traces of old mining trials are to be found in most of the little glens wherever any appearance of a vein is visible, and in some places where there seems to be nothing to have encouraged the search. Those in respect to which no special information is forthcoming are included in the List of Small Workings given on p. 553. In his report for 1858, Smyth mentions that the researches in progress on the south of South Barrule were "very precarious," and that a small shaft had been sunk near Ballamoda farm-house where some surface-stones of ore had been found. Another of these trials was made between 1870 and 1872 on the left bank of the Santon River, 60 yards above Campbell Bridge near Ballanicholas (Sh. 13), rather over a mile south of the East Fox Mines. This was known as the BALLANICHOLAS MINE; it returned 3½ tons lead-ore in 1872. It appears to have been worked at the junction of a granitic elvan with slate (see p. 167); the lode was supposed to have a N.N.W. strike, but seems to have been ill-defined. Smyth refers to the working in his report for 1871, stating that a discovery of ore of remarkably fine quality had enabled a large pile to be raised 13 fms. of driving at the bottom of a 12 fm. shaft, but that it did not look like a lode. In 1873, he mentions that the shaft was being sunk below the 10-fathom level; and in the following year that work had been suspended with the loss of some hundreds of pounds.

LAXEY GROUP.

LaxeY or Great LaxeY Mines.

Standing in the first rank of British metalliferous mines, this great mine has been second only to Foxdale in the Island as a producer of lead-ore, while its output of zinc-blende for a long series of years surpassed that of any other in the kingdom, and indeed was sometimes greater than that of all the other British mines combined. At one period of its career the mine was also a producer of copper ore, though not to a large extent. As the Statistics given on a subsequent page will show, it has, however, of late years shown progressive decline, its annual output lately averaging less than half that of its palmy days.

The mine is established on a north and south lode (average direction about N. 10° W.), having an easterly dip, the country rock being the Lonan Flags of the Manx Slate Series. Although worked to within a mile of the coast, the lode has never been identified in the cliff-section, and was probably first discovered in the bed of the stream. According to an authority quoted by Dr. Berger, it was "opened and wrought by a mining company of Cumberland, about the commencement of the last [18th] century."¹ Mr. A. W. Moore ("History," vol. ii., p. 965) gives reference to documentary evidence of its having been worked about 1782. Feltham, in 1798 ("Tour, etc.," p. 243), mentions a "new level" 160 yards long, a mile and a half up the glen, which he examined. Woods, writing in 1811, gave a full description of the workings, which consisted of two levels from the banks of the river, the upper level, 100 yards long, following a vein nearly 4 feet wide consisting of quartz, blende, galena and some green carbonate of copper, blende being the most abundant; a small quantity of phosphate and carbonate of lead was also noted, and the lead reported to contain as high as 180 ounces of silver to the ton; but where the copper ore occurred, the lead was in small quantity and of poor quality [a feature subsequently found to characterise the lode in its deeper portions also]; in the new level, $\frac{1}{4}$ mile lower down the river, which was 200 yards long in 1808, carbonate of copper and blende alone had been discovered; only three men were employed in the workings.² The vein was again described by Berger in 1814³ and by Macculloch in 1819;⁴ but both observers found the workings abandoned; the latter author mentions the presence of calcareous iron ore (chalybite) and the steel-grained variety of galena. A plan of the mine by J. A. Twigg dated 1826, preserved in the Woods and Forests Office, shows the "Old level" as "wrought out," and a shaft, 34 fathoms deep, communicating with the "New level to unwater the mine."

Work was resumed a few years later on a more extensive scale, with profitable results; so that Cumming in 1847 found the adit to be 400 fathoms long, and two shafts, with drivings, down to 130 fathoms below the adit, employing 300 men.⁵ Since that time the development of the mine has been carried on continuously, the details being published in the periodical reports of the managers which are reprinted in the Manx newspapers.⁶ The principal underground workings of the mine are in the lower part of Glen Agneash (*Glen Mooar*: 6-inch, Sh. 8), where the three deep shafts are situated. At the time of my visit at the close of 1895, the most southerly, or Engine Shaft, had attained a depth of 247 fathoms; the next, or Welsh Shaft, 150 yards farther N., was down to 295 fathoms; and the third, or Dumbell's, 520 yards N. of the last, was 266 fathoms deep, all following the underlie of the vein. These shafts have levels at about every 10 fms. down to the bottom; the pioneer level S. was the

¹ Trans. Geol. Soc., vol. ii. (1814), p. 51.

² "Account, etc.," op. cit., pp. 18-20.

³ Trans. Geol. Soc., vol. ii. (1814), p. 51.

⁴ "Western Isles," vol. ii., p. 577.

⁵ "Isle of Man," p. 308.

⁶ Files of these newspapers may be consulted in the Douglas Free Library.

235, which went 203 yards S. of Engine Shaft ; and the pioneer N., the 255, which at the above mentioned date went 604 fms N. of Dumbell's Shaft ; the length of the deep galleries from end to end of the mine is therefore over $1\frac{1}{2}$ miles. Shallow shafts communicating with the upper workings exist both N. and S. of those above mentioned.

MINERALS OF THE LODE.—The 'lode' varies greatly in breadth and character within short distances, both horizontally and vertically, being sometimes as much as 25 feet in width ('at the 190 fathom level near the shaft,' *vide* Smyth's report for 1857), and sometimes "gradually dwindled to a mere string without a speck of ore, hardly to be recognised by the unpractised eye" (in 110 N.; *ibid.* report for 1870). It usually presents clean well-defined and slightly polished walls of slaty flags, between which the infilling vein-stuff consists chiefly of quartz (with a little chalcedony) in ribs parallel with the walls, and calcite, mixed with more or less slate-breccia and with the metalliferous deposits. Zinc-blende and galena which constitute the principal ores occur alternating with quartz in ribs, and similarly in globular incrustations around 'vughs' or cavities in the lode. The copper-pyrites was mainly obtained in the southern part of the mine (south of Engine Shaft), "especially associated with dolomite,"¹ and occurred in thin strings after the ores of the other metals had dwindled down to an insignificant quantity ; both here and in some of the deep levels farther north it seems to have formed a scanty ragged fringe to the great bodies of blende and galena of the central part of the mine, and its incoming was therefore looked upon with disfavour as indicating the proximity of the limits of these ore-bodies. The galena is of good quality, averaging 40 oz. to the ton of silver. Among other crystalline constituents of the lode are iron-pyrites, chalybite, pyrrhotine (northern part of adit, *vide* Smyth's report for 1882), barytes ("rare in Laxey"²) dolomite ("in perfect rhombohedrons"³) and calcite. Sir W. W. Smyth also notes the following in the old workings, or in the upper part of the lode : melanterite, sulphate of copper, melaconite, pyromorphite ("near Dumbell's shaft"); and steatite ("a white variety, spotted with crystals of zinc-blende, abundant at the 100 fathom level,"⁴) and anthracite ("a 3-inch band on the east wall of Laxey lode, 100 fathom level, S. of Engine Shaft, very pyritous").⁵

ANTHRACITE.⁶—The occurrence of the last-mentioned mineral is of peculiar interest, but the available information respecting it is meagre, and I have not been able to ascertain whether it was a constituent of the lode as Smyth appears to suggest, or belonged to the adjacent 'country' slate-rock. Mr. J. [E.] Taylor in describing the slates in 1864 mentioned the anthracite as occurring in 'thin veins,' and implied that it was interbedded with the sedimentary strata ; but whether his description was based on personal observation or on miner's information is uncertain.⁶ According to the recollection of Mr. Killip, the under-manager of the mine, the substance occurred as a vein, not more than an inch thick and a few inches long, in the "copper ground" between the "Engine" and "Corner" shafts, and formed part of the lode on the hanging or east wall. Captain J. Kitto, however, who also had personal remembrance of the circumstances, thinks that the anthracite lay between beds of the country-rock and like them went off from the lode. The significance of this undecided point is that if interbedded with the slates the anthracite must be regarded as the product of contemporaneous organic growths, like the coal-seams of later times ; but if a vein-deposit it would presumably be akin in its genesis to plumbago and other carbonaceous substances sometimes found in veins. It should be mentioned that no interbedded seam of this character was anywhere observed at the surface in the Manx Slate Series.

¹ "List of Manx Minerals." Trans. I. of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-147.

² *Ibid.* ³ *Ibid.* ⁴ *Ibid.*

⁵ A specimen of this mineral from Laxey is preserved in the Museum of Practical Geology.

⁶ Trans. Manch. Geol. Soc., vol. iv., p. 75.

GRANITIC DYKES AND AGE OF LODE.—The 'lode' appears to be a simple fissure-system extending down to an unknown depth, along which slight movement has taken place without causing much relative displacement of the opposite walls. As bearing upon its age it is interesting to find that in the northern part of the mine the lode breaks across the characteristic elvan-dykes of the Dhoon Granite. The nearest point of the surface-outcrop of this granite is on the hill-top, 1,050 yards east of the underground workings, and there is no indication in the bottom of the mine that the margin of the intrusion is any nearer than at the surface (p. 143). A dyke of micro-granite or quartz-porphry 20 feet in width, striking S. 20°-30° W., probably identical with that seen in the stream in Glen Agneash (p. 144), is traversed by the 255-fm. level (at this point about 1,800 feet below the surface) at 490 yards N. of Dumbell's Shaft; and the lode, carrying a little blende, distinctly cuts across the intrusion without perceptibly displacing it. A second, smaller elvan, 4 feet wide, is seen under similar circumstances 154 yards farther north in the same level. In the southern part of the mine the lode similarly intersects a group of the 'older greenstone' dykes, which were injected into the slates at a period anterior to the intrusion of the granite (see p. 144).

It has already been shown that the sedimentary rocks had undergone extreme deformation before any of these greenstones or microgranites were intruded among them; and moreover, that both sets of dykes have been affected by later movements of great severity. The development of the fissure has clearly been subsequent to the latest of these crushing movements, and cannot have taken place earlier than Carboniferous times, while it may have been much later; so that its metalliferous infilling cannot in any case have begun until towards the close of Palæozoic times, and is more probably long subsequent.

'SLIDES.'—Another factor of much consequence in relation to the age of the lode is that it is displaced at intervals by transverse (E.-W.) 'slides' or dislocations, which are apparently true normal faults. At the southern end of the mine, south of 'Corner Shaft,' the vein seems to have encountered a close-set group of these 'slides' and to have been dislocated and perhaps terminated by them, the various attempts to recover it in the lower part of the glen by day-levels and cross-cuts (including the 'Glyn adit' about 175 fathoms in length) having proved unsuccessful. Farther north the slides have better-defined individuality, the same dislocation being recognised by the miners in the successive levels down to the bottom of the mine. Thus the 'Big slide' intersects the lode at 160 yards south of Engine Shaft, and carries it 10 to 20 feet westward on the south side, the dislocation dipping south at about 70° from the horizontal and splitting into two branches below 30 fathoms. 'Welsh Slide,' emerging at the surface near Welsh Shaft, has a slightly steeper dip in the same direction and affects the lode in a similar manner, displacing it about 6 feet laterally (the chief "copper-ground" of the mine lying between these two slides); but according to the mining plans it unites near the 200 fathom level with another dislocation having in the opposite direction, known as 'Engine Slide,' the two enclosing a huge wedge of the lode between them. Farther north is 'Dumbell's Slide,' dipping south at 60°, and intercepted by Dumbell's Shaft at a depth of 12 fms.; and this is joined at 110 fms. by a slide with a slightly steeper dip in the same direction. In the explorations still farther north other dislocations were passed through, dipping in the opposite direction or northward, and consequently shifting the lode eastward on the south side; and these apparently form a rude northerly boundary to the ore-bearing ground. The average strike of these transverse faults is E 20°-30° N., which is also approximately that of the strata forming the 'country.' Wherever I was able to examine these faults in the mine-workings they presented a rather sharply cut joint-like aspect, generally with a little soft 'dowky' matter or crushed rock between the faces, but with no quartz. The direct vertical displacement which they have effected was estimated to range from 20 feet or less to about 70 feet, but this estimate is of uncertain value, as the movement has probably been oblique.

Though evidence was sought to show whether the deposition of the ore in the lode took place before or after its dislocation by these transverse faults, no very definite conclusion was attained. So far as I could learn, the only case of ore having been found in a slide was that reported to me by Captain W. H. Rowe, who remembered a little "steel-grained" galena being met with in the Agneash Slide between the adit and 12 fathom level. But this absence of ore may be due merely to the 'tightness' and lack of cavities in the fault-planes. The lode itself is usually impoverished in the immediate vicinity of the slides, consisting there chiefly of brecciated 'country rock' with very little quartz or metalliferous infilling; which suggests that it has been shattered by them before the formation of the ribs of quartz and ore within it. Hence, the indications do to some extent suggest a later date for the principal infilling of the lode; and it seems not improbable that the effect of the transverse faults may have been to reopen the older fissure and cause a slight gaping in it where the rocks were firmest and least liable to crumble, thus giving rise to empty spaces in which the crystalline constituents of the lode afterwards segregated. Unfortunately, owing to the absence of newer rocks than the Slates, the district affords no direct clue to the age of the faults; but it is worthy of note that on the Cumberland coast the N.E. to S.W. faulting has been shown to be Post-Carboniferous and Pre-Triassic (see p. 87).

While the metalliferous lode is for the most a single fissure, it is here and there complicated by minor 'branches' going off from it at a low angle, in which occasionally a little ore has been found; and other parallel but unproductive joints or fissures appear to traverse the slates in its vicinity, one of which, known to the miners as the 'East Lode,' has been reached by easterly cross-cuts about 70 yards E. of the main lode. The principal ore-deposits have been found in that part of the mine which lies between Engine and Dumbell's Shaft, occurring vertically in large irregular lenticular sheets showing a general tendency to descend northward. North of Dumbell's, the ore as yet discovered has been dispersed in smaller masses, with wider spaces of barren ground between, and in the most northerly drivings is reduced to mere specks.

THE 'COUNTRY-ROCK.'—In the principal part of the mine the strata belong to the Lonan Flags division of the Manx Slates and consist of firmly welded greyish and bluish sandy and slaty flags; and it is interesting to find that these extend without noticeable change of character from the surface to the bottom of the mine over 1,200 feet below sea-level (p. 33). Like most of the metalliferous veins of the Island, the lode is in the vicinity of the structural axis of the slate series; and the change in the direction of the dominant bedding, from S 20° E. to N. 20° W., may be observed in the mine-workings. South of Dumbell's Shaft the general dip of the contorted strata is at a high angle, usually between 60° and 80°, towards S. 20° E.; but in the 255-fathom level a short distance north of this shaft, the bedding ranges from vertical to 70° or 80° towards N. 20° W., and continues to dip in this direction, at a slightly lower angle, to the N. end of the level. In the deepest level (295 fathoms) the change sets in a little farther south, the N. 20° W. dip being found at about 450 yards north of Welsh Shaft. In both cases the obscure strain-slip cleavage is inclined in the same direction as the dip, but at a much lower angle, usually about 20°. The deep position of this structural anticline corresponds fairly well with its place at the surface. At about 700 yds. N. of Dumbell's Shaft the 255-fm. level passes into darker and more argillaceous strata for about 300 yds. and then into very hard sandy flags, which are probably the commencement of the Agneash Grits that outcrop on the mountain overhead; and as neither type of rock is so well fitted to develop an open fissure as the homogeneous flags farther south, it may be from this cause that the lode is pinched and impoverished in this part of its course. As the northward termination of the profitable part of the mine nearly coincides with the change in the direction of dip of the 'country,' the miners have come to regard this change as itself detrimental; but more probably it is because the N. 20° W. dip ushers in the unfavourable modification of the 'country' that it constitutes an untoward omen.

Precisely as the trials in Laxeý Glen south of the mine, and on the coast, where an adit was driven 50 fms. into the cliff, have failed to discover the prolongation of the lode in that direction, so, also, trials have been made without success on the western bank of Glen Agneash, and again at the head of the glen (where it is known as Glion Ruy), to discover its northward extension. In this direction it would have approached nearer the outcrop of the Dhoon Granite than in any other part of its course; and the deterioration of the lode in the underground workings north of Dumbell's Shaft, as well as the poverty of the veins which have been tested at the Dhoon (p. 528) in close proximity to the igneous boss, tell strongly against the supposition that the presence of the metalliferous deposits is due to the contiguity of the granite (see also ante, pp. 491-2).

ANNUAL OUTPUT OF LEAD, ZINC, AND COPPER ORES FROM THE
GREAT LAXEY MINE BETWEEN 1845 AND 1900.

(From *Mineral Statistics in Mem. Geol. Survey, vol. ii.* (for 1845 to 1847); *Records of the School of Mines, vol. i., pt. 4* (1848 to 1852); *Home Office, Mineral Statistics* (1853 to 1900).)

Year.	Copper-ore. ¹	Zinc-Blende.	Lead-ore.	Silver contained in Lead-ore.	Total Estimated Value.
	Tons.	Tons.	Tons.	Ounces.	£
1845	79	—	327		
1846	92	—	220		
1847	60	—	375		
1848	—	—	695		
1849	—	—	815		
1850	—	—	810		
1851	—	—	900		
1852	—	—	800	32,400	
1853	—	—	698	28,130	
1854	64	1,435 ²	900	32,336	
1855	—	3,990 ²	800	24,400	
1856	94	3,000	700	24,675	
1857	169	2,909	500	17,625	
1858	403	2,777	600	21,068	
1859	354	—	800	19,826	
1860	333	3,181	800	16,936	
1861	731	3,255	600	11,184	
1862	942	691	700	16,380	
1863	1,263	2,298	800	19,440	
1864	127	5,356	1,250	59,000	
1865	1,317	5,488	1,500	65,293	
1866	294	4,960	1,800	81,054	
1867	400	5,362	2,100	93,365	
1868	412	3,278	2,300	105,020	
1869	400	7,208	2,200	101,244	
1870	300	4,067	2,130	87,760	
1871	100	5,718	2,300	98,221	
1872	300	2,973	1,300	52,316	
1873	—	5,370	2,355	94,870	

Value of lead-ore not stated before 1874.

¹ In *Mem. Geol. Survey, vol. ii.*, p. 715, the earlier statistics on next page are given respecting the annual sales of Laxeý Copper-ore at Swansea. The output of the other ores for the same period is not recorded.

² Largest in the United Kingdom.

Year.	Copper-ore.	Zinc-Blende.	Lead-ore.	Silver contained in Lead-ore.	Total Estimated Value
1874	—	6,925	2,100	86,268	£58,24
1875	—	11,753	2,400	107,420	90,91
1876	75	8,582	2,500	57,460	85,04
1877	8	8,645	2,222	94,749	77,85
1878	30	9,411	1,395	49,898	52,94
1879	—	7,200	1,200	40,500	46,71
1880	35	7,425	1,300	24,745	53,44
1881	—	7,568	1,700	52,50[0]	59,11
1882	—	7,750	1,755	70,200	19,94
1883	200	4,720	1,540	61,600	45,17
1884	—	5,625	1,537	61,188	43,44
1885	236	5,340	1,588	63,219	42,71
1886	—	4,715	1,765	72,030	47,65
1887	—	4,540	1,545	63,052	42,24
1888	46	4,600	1,535	62,643	42,11
1889	—	3,900	1,615	65,908	43,64
1890	—	3,844	1,430	58,359	48,33
1891	—	2,825	1,120	45,708	32,71
1892	—	2,360	943	39,427	24,71
1893	—	2,145	902	36,811	18,71
1894	—	2,040	527	21,507	13,04
1895	—	1,417	403	16,447	8,91
1896	—	1,180	399	15,884	8,71
1897	—	1,610	247	10,080	8,85
1898	—	1,575	138	5,632	9,44
1899	—	1,390	158	6,448	11,85
1900	—	1,216	95	3,877	7,44

Appendix—SALES OF LAXEY COPPER-ORE AT SWANSEA, 1828-1837

Year.	Tons.	Year.	Tons.
1828	28	1838	121
1829	161	1839	183
1830	238	1840	278
1831	283	1841	368
1832	341	1842	406
1833	249	1843	207
1834	268	1844	46
1835	77		
1836	89		
1837	69		
			Total 3,412

North LaxeY Mine.

The location of this mine is in the upper part of the Cornah v 1½ miles west of Corran (six-inch, Sh. 8). It has been in operation, short intervals of quiescence, since 1856, and has produced in the aggregate a considerable quantity of lead-ore, but not as yet sufficient to repay

¹ Plus value of copper, not stated.

² There is evidently an error in the statistics here ; £30,000 should probably be added.

cost of working. The following description is based on my personal examination of the mine in 1895, and on information then kindly placed at my disposal by the manager, Mr. J. Corlett. Some details of interest regarding the earlier workings, which are now for the most part inaccessible are added from Sir W. W. Smyth's Reports.

The mine is worked on a lode which crosses the bottom of the valley in a nearly north and south direction, with an underlie or dip westward. Two shafts have been sunk, 70 yards apart, the South Shaft to the depth of 110 fathoms and the North Shaft (in December, 1895) to 174 fathoms. The mine has levels at 12, 27, 38, 50, 60 (the two last in South Shaft only), 73, 84, 96, 110, 121, 136, 146, and 170 fathoms; the longest or pioneer levels were the 146 northward, and the 60 southward. The 'lode' is mainly indicated by a quartz vein, bunchy in character, sometimes only 2 or 3 inches wide or even nipped out to a mere joint in the slate-rock, and sometimes swelling to a width of 3 or more feet, and then often full of crystal-lined 'vughs' or cavities which when first tapped discharge water, but soon dry up. It contains in places ribs and bunches of galena and scattered patches of other minerals, including barytes (in the deeper workings), pyrites, etc. The fissure does not appear to represent a fault of any consequence. The country-rock, which dips steeply north-westward, is a firm dark slate, interbedded at intervals with hard bands of quartz-veined grit (see p. 141), one of which, 3 feet in thickness, was well exposed at the bottom of the North Shaft at the time of my visit. The ore-bodies have shown a tendency to sink northward, being met with at shallower depths in the southern than in the northern part of the mine.

Turning to Sir W. W. Smyth's reports¹ we find mention in 1857 that at 10 fathoms there was a little ore, only a few inches wide; in 1860 the South Shaft was at 40 fathoms, and the lode still small and producing only a little ore; in 1865 some ore ground had been found in the 60-fathom level south, but the "end got into black ground, bedded rather flatly," and not promising; and in the following year it is noted that the same level had "poverty-stricken white quartz for its veinstone." In 1869, in the 110 level of the South Shaft the lode proved quite poor on the south, but bolder and better on the north; and the discovery of ore in the 96 and 84 north drivings, where there was "a really tolerable lode," led to the renewed sinking of the old [North] Shaft which had previously stopped at 38 fathoms. In 1872 the North Shaft was down 120 fathoms, and the lode there 4 or 5 feet wide, but quite worthless; and in the 110 level half-way between the shafts the vein was also of good size, but calcareous and unprofitable. In 1876, it is noted that the lode at 136 fathoms down was sprinkled with lead and zinc; and in the following year that at 146 fathoms it was "dull quartz with a few large crystals of calc-spar in the cavernous hollows."

In the annual "Mineral Statistics," returns of lead-ore from this mine are given for all the years between 1857 and 1878 inclusive; also for 1880-1, 1891-4, and 1897, amounting in the aggregate to 1,763 tons.

Glencherry Mine.

This name was given to a small mine in the bottom of the Cornah Valley 650 yards east of the North Laxeey Mine, with which it has since been amalgamated. Work was carried on here, chiefly between 1865 and 1875, on a north and south lode with an easterly underlie, which yielded a small quantity of lead ore. Two shafts were sunk, the South Shaft to 15 fathoms, and the Engine Shaft to 35 fathoms, with levels at 15, 20 and 35 fathoms.² Sir W. W. Smyth describes the underground appearances in his reports as follows³:—"In 1866, when the shaft was down 8 fathoms, it was "on a lode 5 or 6 feet wide yielding extremely promising stones of weathered galena with incrustations of green and of white lead ore;" in

¹ MSS. in Woods and Forests Office.

² Information from Mr. W. H. Rowe.

³ MSS. in Woods and Forests Office.

1867, the 15 fathom level had been driven 12 fathoms north, and a little ore; in 1868, it is noted that the favourable symptoms had short duration, and the ground very changeable—the 20 fathom north had a little ore which dwindled away after a few feet; in 1870 and 35 fathom levels had been driven for some fathoms without more than a mere sprinkling of ore; and in 1871, the 35 level had been driven some 15 fathoms, showing a lode 2 to 3 fathoms with no other mineral than a little pyrites in sight.

East Laxey Mine.

Under this title an unsuccessful trial for copper, on which thousands of pounds were expended, was carried on between 1866 and 1868 in the Cornah Valley 600 yards west of the bridge at Corran (Sh. 8). The adit was driven from the bank of the stream for 65 fathoms in the direction of N. 30° W. on a hard quartzose lode, underlying what is said to contain little pockets of copper pyrites and iron pyrites. A shaft was sunk to 20 fathoms, with a level at that depth for 40 fathoms northward. Another adit was driven, for a few fathoms only, on the south bank of the stream. No saleable quantity of ore was produced. Sir W. W. Smyth refers in his report for 1867 to the driving of a “a miserable-looking hard vein with but a few specks of copper here and there”; and in 1868 states that he examined the 20 level for 40 fathoms north, and found a lode all the way, without promise.

East Snaefell Mine.

The company using this title was formed about the year 1864 for the supposed extension of the Great Laxey lode in the upper part of the Cornah Valley, 650 yards above the ‘North Laxey Mine.’ An adit (indicated on the six-inch Ordnance map, Sh. 8) was driven S. of the hill-side, on a gossany clayey ‘lode’ underlying east, but no ore was found.¹ Smyth writes of these trials in his report for 1867: “some short drivings and the sinking of a sump for a few feet have shown that there are lodes in this ground, but nothing of promising appearance, far less productive, has been seen.” The company afterwards transferred its operations to the “Glencherry Mine.”

Snaefell Mine.

This mine, on which work was seriously commenced about the year 1864 and has been continued, with some interruptions, up to the present, is situated at the eastern foot of Snaefell on the north branch of the waters of the Laxey River, 3 miles N.W. of Laxey village. The lode was discovered in the bed of the stream, strikes about N. 20° W. and dips to the north, but swings to N. 30°–35° W. towards the northern extremity of the mine. Its underlie is eastward at about 75° and is horizontal. It consists of a belt of crushed slaty rock, often interpenetrated by strings of quartz associated with dolomite, galena, zinc-blende, and a little copper-pyrites, iron-pyrites; and pyrites (“in the form of acute hexagonal pyramids”). Sir W. W. Smyth records² impure graphite (“100 and 130 fathom-levels”) and manganese (“small crystals in small isolated ‘vugs’ or locks,” found about 1876). The width of the space recognised as ‘lode’ varies from 6 to 60 feet or more; but its limits are generally ill-defined, and it is said to have ‘branches’ in places on both sides, with more or less broken

¹ From information obtained from Mr. W. H. Rowe.

² *Ibid.*

³ “List of Manx Minerals,” op. cit.

rock between; and the lode is considered to be most favourable where these 'branches' fall into it. This broken ground probably marks a line of faulting which may be of considerable magnitude, though the highly contorted and complex structure of the strata precludes any trustworthy estimate of the displacement. The mine is placed on the narrow belt of banded slates with gritty intercalations which form the passage beds between the Barrule Slates on the west and the Agneash Grits on the east, but the deeper northward workings appear to enter the Barrule Slates. At the time of my examination in 1895, it consisted of a single shaft, following the dip of the vein to the depth of 171 fathoms, with levels, below the adit, at 25, 40, 60, 74, 85, 100, 115, 130, 141, 158, and 171 fathoms, chiefly driven northward under the mountain. The most northerly point of the mine was the 130-fathom level, which was 530 fathoms out from the shaft; and the most southerly, the 141 level, out 60 fathoms. The levels communicate with each other by a series of winzes connecting with the adit-level which enters the hillside 100 yards N. of the shaft.¹

While a little ore has been found in many places in the lode, the principal bunches hitherto discovered lay at 60 to 80 fathoms north of the shaft in the upper levels, and at over 250 fathoms north in the lower levels. Including 1900 the total output of ore from the mine since the year 1870, recorded in "Mineral Statistics," is 4,567 tons lead-ore and 8,926 tons zinc-blende.

The galena averages 14 to 16 ounces of silver per ton. The copper-pyrites is sparsely distributed, occurring chiefly where blende is most abundant. No payable quantity of ore has been discovered south of the shaft, either in the deep levels or in the trial adits in the valley below the mine. One of these trials, on the south bank of the Laxey River 200 yards below the confluence of its two main branches, was driven W.S.W. for 80 fathoms to cross-cut the lode, and then southward along the lode for about 80 fathoms farther.

Polished (graphitic?) and slickensided surfaces are very conspicuous in the vein, especially among the darker slates, the striae on some faces being vertical, and on others horizontal or inclined. The 'dominant dip' of the rocks (see p. 145) in the neighbourhood of the mine is towards N.N.W.; but underground the dips were found to be variable, and frequently towards the unusual direction of N.E. or E.N.E., probably denoting local disturbance along the line of faulting. In one place the lode is cut by a 'cross-course,' which is clearly a later fault, striking N. 30° W. and having southward, the effect of which is to shift the metalliferous vein 8 feet to the westward on the north side. The position of this 'cross-course' in the 141 fathom level (where I examined it) is about 205 fathoms N. of the shaft; the lode is somewhat enriched in its vicinity, especially in blende. One or two small sheared igneous dykes of the basic type so numerous in the Manx Slates were observed in the country-rock adjacent to the lode.

Block Eary and other Trials near Snaefell.

In the valley of the Block Eary feeder of the Sulby River, at the foot of the northern slope of Snaefell Mountain, an adit was driven for 100 fathoms south-eastward in the river-bank S. of the farmstead of Block Eary, and another in the opposite direction in the little glen 250 yards W. of the farm, on a vein which is said to have been similar in character to that of the Snaefell mine, with which it was supposed to be continuous; but no ore of value was discovered.² The Snaefell lode was also sought

¹ A plan and description of the mine is contained in the Official Report of Dr. C. Le Neve Foster to the Home Office on the accident in May, 1897, by which twenty men lost their lives through the poisonous gases engendered by a fire in the timbers of the 130 fathom level. (Blue Book. "Snaefell Lead Mine Accident." 1898.)

² From information furnished by Capt. J. Kewley.

for in the opposite direction, south of the valley of the Laxey River, but Sir W. W. Smyth noted in his report for 1871¹ that only some indistinct fragments of vein were found in these workings. Several other profitless trials were made in Laxey valley between the Snaefell and Great Laxey mines, one of which, known as the Glenfoss level, is briefly described in Smyth's report for 1865.²

Glen Roy Mine.

This mine, on which very large sums were expended both underground and at the surface, is situated in Glen Roy near Riversdale, 2 miles west of Laxey. It seems to have been begun about 1864 as an offshoot of the Great Laxey Company, but was subsequently worked by an independent company, with disastrous results. It was finally abandoned about twenty years ago. As the returns of ore from the earlier workings seem to have been combined with those of Great Laxey the data for estimating its total produce are not available. In the years 1877, 1878 and 1882, when separate returns were made, the aggregate (in "Mineral Statistics") is 9 tons 9 cwt. of lead ore, and 136 tons 9 cwt. of zinc ore. The shaft was sunk to a depth of about 122 fathoms, with levels at 10, 25, 40, 55, 65 [100?] and 104 fathoms, on a north-westerly lode, fading eastward.³ The presence of a large dyke of greenstone in the vicinity of the lode has been noticed in a previous chapter (p. 160). The following excerpts from Sir W. W. Smyth's reports for the years between 1864 and 1882 will serve to show the principal features of the mine:—In 1864 the operations are referred to as a "small trial"; in 1867 we learn that at 18 fathoms there was a better lode of 2 to 3 feet wide, with a gossany leader or branch containing some good stones of lead-ore; in 1868 the 25-fathom level had been driven a few fathoms north-west on the lode, with about $\frac{1}{2}$ -ton lead ore and 1 ton blende per fathom; in 1869 the same level, extended 30 fathoms, had yielded some good ore, and the 40-fathom level, driven some 9 fathoms, showed "a pretty little rib" chiefly of zinc blende, "but there is nothing that savours of more than distant promise." In 1873 the 50 [? 55] fm. level was a long way north, with one little bunch of ore, while the 65-fathom level had been driven 25 fathoms each way but showed no promise. In 1876 the mine had recently been reopened, and a little zinc-blende was found in the 40-fathom level by a cross-cut through what was supposed to be the wall. In 1877, at the bottom of the shaft below 65 fathoms the lode was only 4 inches wide at one end, and at the other showed two strings with 4 feet of ground between them, but not a speck of lead or zinc. The 65-fathom level had been driven 73 fms. [?] north and 80 fms. [?] south, and in the 25-fathom level a little blende had been found in a portion of the lode turning some 15° west of south. In 1879 the 100 [? 108] fm. level was 11 fathoms out on "some appearance of a vein, with a few cavities and crystals of dolomite, but utterly sterile for useful mineral." In the following year this level had come upon some good ribby lead ore, but it proved an isolated pocket. And finally, in 1881, we learn that the deepest level, at 108 fathoms, was out 70 fathoms with only one little blink of ore; that the shaft was deep enough for a 122 fathom level; and that an anomalous bunch of a few tons of very good ore had been found in the 25-fathom level in connection with a 'slide.' The next report mentions that the mine was dismantling.

Dhoon or Rhennie Laxey Mine.

The operations known by this name, on which many thousands of pounds were expended without any return, were made for the purpose of testing a supposed lode occurring in Dhoon Glen, 400 yards east of the main

¹ MSS. in Woods and Forests Office.

² *Ibid.*

³ There is some discrepancy in particulars between the plan of this mine deposited at the Home Office (No. 1509 in "List of Plans of Abandoned Mines") and our other sources of information. The Home Office Plan gives the shaft a depth of 108 fms. only.

road from Laxey to Ramsey. The early workings consisted of a shaft sunk in the glen on the 'lode,' from which a little lead ore was obtained. This shaft ultimately attained a depth of about 65 fathoms, with drivings at 10, 18 and 20 fathoms, in the last of which, north-west of the shaft, a little zinc-blende was revealed. All the workings were in the slate rocks. The most ambitious part of the later operations (between 1859 and 1869) took the form of a deep adit-level, starting low down in the great cliff of slate 500 yards S. of Dhoon Bay and going for 315 fathoms in a west-north-westerly direction as a cross-cut to intersect the vein, and afterwards pushed to within about 250 yards of the margin of the Dhoon Granite. The course of the lode is supposed to have been W. 10° to 20° N., with a southerly underlie.¹ The following excerpts from Sir W. W. Smyth's reports supply further information regarding these now inaccessible workings.² In 1858 the vein is described as 4 to 6 feet wide, with occasional spots of lead ore; in 1866 Smyth states, "I regretted to pass through a long series of workings at the 20 fathom level which have proved entirely unproductive; a few small strings only, which run W.N.W. carry some lead ore, but they seem unimportant." In 1868 it is mentioned that the shaft had been holed to the level, but only a little zinc-blende found in the process, and that all the way in the level ($\frac{1}{2}$ of a mile) to its mouth, not an available spot of mineral had been seen. In 1869 this level had been advanced 110 fathoms beyond the shaft, and the end was following a vein through soapy grey slate, but not exhibiting a speck or sign of any kind of ore.

Minor trials in the same glen included a short cross (10 or 12 fathoms) in slate on the spur between two streams, 200 yards E.N.E. of the shaft; and another in the upper part of the glen, a few yards west of the high road, said to have a length of 35 fathoms, and to continue throughout in the tough boulder clay in which it starts.³

SOUTHERN GROUP.

Bradda Mines.

As stated in the introductory notes to this chapter, these mines are probably the most ancient in the Island, and were worked at a period anterior to the oldest records. They seem always to have been carried on fitfully and with long intervals of quiescence, just as during the 19th century. Copper and argentiferous galena have been the principal ores obtained, the latter especially in the northern part of the lode. Permission was asked in 1858⁴ to raise iron-pyrites from the mine, but Sir W. W. Smyth gave the opinion in his report for that year that the mineral was not likely to occur in quantity.

Cumming remarks that these mines "seem to have been wrought to some extent at the beginning of the seventeenth century, but have latterly been almost abandoned."⁵ Chaloner, in 1656, after mentioning the occurrence of lead-ore containing silver at this place, adds⁶:—"The Veins of this Mine, by it's brightnessse, may plainly be discerned in the Rock towards the Sea; but it seemeth not possible to be wrought, in regard the Sea beats upon it constantly at High-water, unlesse it may be done by Mining within the Land; a tryall whereof were worth the undertaking, in regard of the great benefit that possibly may ensue thereof." Feltham in 1798 ("Tour," etc., op. cit., p. 213) mentions that the mines though closed at the time of his visit, were worked and the ore brought from the shore in boats, and then carted to the smelting house at Port-le-Mary. Woods, Berger and

¹ Information chiefly from Mr. W. H. Rowe.

² MSS. in Woods and Forests Office.

³ Information chiefly from Mr. W. H. Rowe.

⁴ Documents in Woods and Forests Office.

⁵ "Isle of Man," 1848, p. 165.

⁶ "A Short Treatise, etc." p. 8.

Macculloch, early in the past century, found them standing idle, the last-mentioned author stating (in 1819) that they had been abandoned "twenty years ago." A plan of the workings, dated 1826, is preserved in the Office of Woods and Forests.¹

Work was resumed soon after Cumming wrote, as there is a return of 25 tons of lead ore from them in 1850; and similar small quantities are recorded intermittently between this date and 1863, the returns for the whole period showing 178 tons lead ore and 146 tons copper ore. The "South Manx Mining Company" which had been prosecuting the work seems then to have come to an end; but between 1866 and 1875 the "Bradda Mining Company" resumed operations, with a total output, as shown by returns between 1869 and 1874, of 364 tons lead ore and 193 tons copper ore. In 1881 the mine passed into other hands, and a new "Bradda Mining Company, Limited," was instituted, which ceased working in 1884. The returns of this company (1881-1883) give a total of 478 tons copper ore. The output from these mines seems never to have approximately reached the cost of production.

The lode, as already mentioned, is very conspicuous in the cliff on both sides of Bradda Head. On the south it occurs as a nearly vertical rib of white quartz and fault-breccia 30 to 50 feet wide, with well-defined walls, rising over 120 feet up in the cliff. It strikes N. 5° E. across the headland for 700 yards and reappears on the coast opposite Creg Harlot (six-inch map, Sh. 15), forming in places the face of the high cliff until truncated by a sharp curve in the coast-line. It is to these sections that Sir W. W. Smyth referred in describing the Bradda Lode as "the noblest surface exhibition of a mineral vein to be seen in Europe."²

At its southern extremity the underlie of the vein is eastward at about 10° from the vertical. The quartz is full of cavities or 'vughs,' and the metalliferous contents are distributed irregularly in detached strings and patches. I am informed that at South Bradda the lode was found to 'pinch' rapidly in the workings below sea level, and that in the deepest part crushed slate rather than quartz was its chief constituent. The fissure appears to mark a fault cutting off the eastward prolongation of the flaggy grits of the headland; but the extremely contorted arrangement of the rocks in this vicinity hides the true relations of the strata. It is important to note that the vein, like most of the metalliferous lodes of the Island, lies close to the main structural axis of the slates (see p. 30).

At its northern outcrop the fissure is less sharply defined, and appears to have split into two or more branches with shattered rock between them, the western branch being distinguished as the 'Bulwark Lode.' In this part of its course a small dyke of (Tertiary?) olivine-dolerite, 1 to 2 feet wide, is seen in the cliff to run along the lode, thus furnishing an especially interesting example of the association of the dykes of this type with the metalliferous deposits. In this case it is evident that the vein was in existence prior to the intrusion of the igneous rock; and no distinct indication is forthcoming to show whether the dyke has been the means of introducing or concentrating the ores in the fissure, as is suggested in some other instances (p. 488). The dyke is probably an offshoot from a broader intrusion visible at low tide on the shore 220 yards S. of Creg Harlot, which strikes away from the lode in the usual direction of the olivine-dolerite group, viz., W. 35° N. Apparently while the main part of the dyke has held to its original course, it has thrown off a branch northward on intersecting the lode. On the opposite or eastward side, the course of the main dyke is indicated by a small outcrop at the side of a fence 250 yards inland, in the same line of strike. The intrusion was seen in the North Bradda mine-workings by Sir W. W. Smyth, who in his report for 1873, after describing the 70-fathom level north of the shaft as being in a cavernous quartz lode with very little appearance of copper, remarks:—"the south driving of the same level has been strangely interfered with

¹ Of doubtful value; probably incorrect.

² Bevan's "British Manufacturing Industries," 2nd ed., p. 15. (London, 1878.)

by trap dykes, which in some places appear to border, but in others cut right across the lode, filling up a great portion of the space between the walls."

The workings on the vein are in three separate groups:—the South Bradda Mine, at the foot of the cliff at the southern outcrop; the North Bradda Mine, in a similar position at its northern extremity; and a set of workings at a higher level, on the top of the headland about half-way between, which connect with an adit-level driven in from the cliff.

At South Bradda the older workings were carried on by means of an adit about half-way up the cliff, driven northward along the lode and connected with shafts from the surface of the headland and with sinkings where the ground was productive. The largest patches of ore seem to have been found in this locality. The later operations include a level over 100 fathoms long, driven upon the lode at a little above high-tide, with a rise connecting with the higher workings; and a shaft sunk from the base of the cliff to a depth of 30 fathoms, with a level along the vein at 20 fathoms, which disclosed nothing of importance.

At North Bradda there is, similarly, a series of old galleries in the face of the cliff, with newer workings descending below sea-level. The shaft at the base of the precipice is stated to have been carried to a depth of 72 fms. with levels at 27, 40, 50, 60 and 72 fathoms, mostly driven northward on the lode. The longest of these levels was the 60 fathom, which appears to have been carried 70 to 80 fathoms N. of the shaft, with poor results. Some ore was won in the 40 and 50 fathom levels, and a little lead in the 72 fathom S. The mine made 200 gallons per minute of salt-water. One of the higher galleries of this mine was driven south to connect with the 'Spittals Shaft,' which was sunk from the upper surface of the headland. The plan of the mine prepared by J. A. Twigg of Chesterfield in 1826, now preserved in the Office of Woods and Forests, shows a through communication between North and South Bradda by an adit a little above sea-level, but this connection is not shown on the later plans to which I have had access. The workings above sea-level were the most productive of the mine both in the cliff and on the top of the headland; and Smyth notes (in his report for 1873), "It is a matter of reasonable disappointment that this great lode both here [North Bradda] and in the southern workings at Spittals Shaft has manifestly deteriorated in depth." The width of the lode in the upper part of the mine was in places between 10 and 11 fathoms.¹ The vein was everywhere 'streaky,' and without continuous ore bodies. A little native copper ('moss-copper') is reported to have occurred in the parts of the mines highest above sea-level. The following minerals from the lode are recorded by Sir W. W. Smyth:—Malachite; Cuprite ("in minute octahedral crystals at the 40 fathom level"); Melanconite; Copper Pyrites; Copper Sulphate (old workings); Atacamite ("copper-ore changed under action of the sea-water—Old Mine, North Bradda"); Galena (argentiferous); Cerussite; Marcasite; Chlorite ("with quartz"); Agate ("parts of the vein-quartz in the Bulwark lode, North Bradda"); Hydrated Oxides of Iron (Ochre and Umber; "sometimes as gossan of lodes as at Ballacorkish and Bradda").²

As the workings are now inaccessible, special value attaches to Sir W. W. Smyth's descriptive reports, from which, in addition to the passages already quoted, the following details respecting the character of the lode have been culled. In 1858, Smyth mentions that at North Bradda "the eastern part of this huge lode presents a rib, between 2 and 3 feet wide, of softer character, which was largely worked for lead ore under the Duke of Athol, and a little is still obtainable in the 'backs.'" In 1859, the workings at South Bradda are described, where the adit had been cleared, the lode cross-cut, and a 20 fathom level driven some distance below the adit, "but although copper-pyrites, galena, iron-pyrites, and carbonate of

¹ For the above details I am chiefly indebted to Messrs. R. Barkell, J. Kewley, and W. H. Rowe.

² See "List," in Transactions I. of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-7.

iron are all there, they are in too small quantity to be of any value." It is also mentioned that three shallow shafts opened on the hill above, and levels driven or re-opened there, had discovered large workings of the 'old men,' but very little ore. In 1860, "from North Bradda, at last, some ore has been raised and sold," a very fair course of lead ore having been found in a winze down about 14 fathoms on the eastern lode. In 1868, we learn, "the Bulwark lode or farthest point W., under the sea, has so far been a disappointment, containing little else than quartz with an agate-like structure." In 1871, the North Bradda shaft was down 9 feet below 70 fathoms, and "here the lode is a great quartzose cellular mass of the hardest character, streaming on all sides with salt water, and containing only small spots of copper ore." In 1872, the workings at Spittals Shaft are described as being 25 fathoms below the adit from the cliff, which reached the shaft at 54 fathoms from the surface, the lode keeping its great size here "in all 50 or 60 feet wide, inclusive of the 'dunk' or soft argillaceous lode, and the 'Bulwark' or western quartzose part," but copper ore occurred only in spots. On the last re-working of North Bradda, it is noted in the report for 1883 that the 40 fathom level, driven 60 to 60 fathoms N. of the shaft, had ore said to run 3 or 4 tons per fathom, but "a cross-course had disordered the lode in the end."

Coast south of Port Erin.

If the Bradda Lode be continuous southward in the same line of strike, it should be again intercepted by the coast about $\frac{1}{2}$ mile S. of Port Erin Bay; and we find in this locality a comparatively small but well-marked vein, with an easterly underlie, in the recess of Bay Fine, consisting of quartz and fault-breccia with iron pyrites. The strike of this vein, however, is N. 10° W., which is somewhat to the seaward of Bradda Head; it may possibly be a branch of the main fissure. At Aldrick, a similar recess $\frac{1}{2}$ mile farther south, another fracture is revealed, striking about N. 3° W. and having eastward, which emerges again on the shores of Calf Sound near Carrick Noy (six-inch, Sh. 18) 500 yards farther south, where it forms a broad lode. This has been tested by an adit reported to be 15 to 20 fathoms in length, from which a little copper-ore was obtained. I was informed by a miner who had worked both here and at Bradda that this lode resembled exactly the Bradda vein, of which it is regarded as the prolongation. If the identification be correct, the Bradda vein must have been shifted for 600 or 700 yards to the westward of its strike, either by a change of direction or by cross faulting. It is more probable however that, as at Ballacorkish, the ground is gashed by a set of approximately parallel but discontinuous fissures. There are no doubt later east and west faults here, as in other localities; but it is scarcely likely that these are large enough to carry the Bradda vein to Aldrick.

Ballacorkish, South Foxdale, or Rushen Mines.¹

Though not permanently profitable, these mines have made a considerable output of lead and zinc ore, of which they are the only workings in the south of the Island to yield an appreciable quantity. Their early history is obscure, but the vein appears to have been worked and abandoned prior to 1811.² It is also mentioned by Macculloch in 1819 as an abandoned working.³ The mines lie in the Manx Slates, about half a mile W. of the village of Colby in the parish of Arbory, on the lower slopes of a spur from the hilly axis of the Island. Work was resumed

¹ Unless otherwise indicated, the account of this mine is based on my personal examination of the plans and part of the workings, supplemented by information supplied by Mr. F. Kitto, the manager of the mine.

² G. Woods, "An Account," etc., op. cit., p. 12.

³ "Western Isles" vol. ii., p. 574.

about 1862 and carried on more or less intermittently at the one or other of two shafts until 1893, latterly under the title of the Rushen Mines. The aggregate returns, as given in "Mineral Statistics" between 1864 and 1894, show a total output of 3,693 tons lead ore, 2,864 tons zinc ore, and 138 tons copper ore.

The mines comprise two separate workings, not connected underground, the main shafts of which are about 600 yards apart. These workings appear to be on different lodes, or otherwise upon a lode which has suffered considerable lateral displacement. The lode or lodes have a general northerly strike, but while in the South or Ballacorkish mine the average direction is 2° to 5° W. of N., in the North or Rushen Mine it is about 10° E. of N. The hade or underlie is in both cases principally westward, at from 10° to 20° from the vertical, but with local deviations bringing it over in one part of the mines to the opposite quarter.

The South Shaft has been sunk to a depth of 75 fathoms, with levels at 12, 24, 36, 60, and 75 fathoms. The longest level is the 60 fathom, which has been driven about 490 yards north and 130 yards S. of the shaft. The North or 'Phosphate' Shaft had a depth at the time of my visit in 1893 of 60 fathoms, with levels at 15, 30, 45, and 60 fathoms, of which the 45 fathoms went 60 yards S. and 260 yards N., and the 60 fathoms about the same distance N., these being the pioneer levels of the mine. In the uppermost part of the mines a little copper ore was obtained, while the lower levels yielded only galena and zinc-blende, the latter chiefly on the western side of the lode. The ores were 'bunchy' and irregular in their mode of occurrence throughout. In describing the uppermost level in the S. shaft in his report for 1869, Sir W. W. Smyth remarks "in the best part of this . . . the lode was as much as 5 or 6 feet wide, with more massive ribs of ore than were anywhere to be seen in the Island except only Foxdale and Laxey."

The galena of the south mine was richer in silver than that of the north, the former being stated to run 15 to 16 ounces to the ton and the latter only 3 or 4 ounces. The water percolating along the lode and pumped from the shafts averaged from 30 to 35 gallons per minute for each mine.

Besides the ores mentioned above, the following minerals are quoted in Sir W. W. Smyth's list¹ as occurring in the vein:—Pyromorphite [phosphate of lead, from which the N. shaft derived its name], Cerussite, Chlorite ("according to Captain Barkell"), and Ochre and Umber [decomposed dolerite?]. The country-rock chiefly consists of rather flaggy slate; thinly bedded grits with slate partings were revealed in a short cross-cut E. in one of the lower levels.

The main geological interest of the mine lies in the relation of the lode to a dyke of olivine-dolerite, and in the cross-faults by which the metalliferous vein is thrown. The olivine-dolerite is apparently one of the Tertiary dykes (see p. 327) which diverges from its W.N.W. course on encountering the lode and follows it for a short distance. It is probably identical with the intrusion revealed in the bed of the Colby River a few yards below the corn mill, and again in the little glen 400 yards W. of Colby under the garden of Ballasherlocke (see p. 185).

As previously stated, the relations of the metallic infilling of this lode to the intrusive rock afford important evidence as to the age of the ore-deposits, a study of the facts leading to the conclusion that although the lode existed as a rock-fracture previous to the intrusion, some part if not all of its metallic contents were subsequently accumulated, therefore attaining their present position at a comparatively late geological period (p. 489).

SOUTH MINE.—The dyke was first reached in the northward drivings of the South Mine within about 200 yards of the shaft and was more or less continuous thence to the end of the levels, accompanying and forming part of the lode, the ore lying sometimes to the east, but oftener to the west of it.

¹ Trans. Isle of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-7.

This portion of the mine was inaccessible at the time of my survey, but is described, with especial reference to the intrusion, in Sir W. W. Smyth's official reports. The presence of the dyke is first mentioned in his report for 1870¹; in the following year Smyth notes the adit being stopped "on account of the apparent destruction of the lode by greenstone"; and in 1878, that in a deeper level the "black-rock or dolerite" made its appearance and seemed to militate against the productiveness of the vein. In 1879, he compares the intrusion to the [Carboniferous] igneous rock of Scarlet Point [from which it is, however, distinct, see p. 325] and describes its occurrence in the 60-fathom north level, at that time 210 fathoms out from the South Shaft, as follows:—"I regret to add that the dolerite or black igneous rock . . . has for the last 35 fathoms completely overpowered the lode so that in the latter part hardly a trace of it is seen. Before that, it had accompanied the lode in a narrow band of 6 inches, which had appeared to do its productive qualities no harm. . . . There are hitherto but few precedents to go upon with reference to this dolerite and basaltic rock, but it is evident it is a question of much importance in this part of the Island from its action here, as well as at Central Foxdale, and in a minor degree at Bradda." In 1880, in describing the further progress of this level, he mentions that the lode was a mere string, not yet out of dolerite in which it has "been encased for 80 fathoms length,"—thus distinctly implying that the 'lode' proper is newer than the intrusion.

NORTH MINE.—In the North Mine, where it was practicable in 1893 to examine the intrusion in the lower levels, I found the principal dyke to have a thickness of from 6 to 12 feet. Small fliers of the same rock occurred among the lode-stuff and were themselves sometimes dappled with lead-ore throughout, this association suggesting that part, at least, of the metalliferous contents of the vein had been introduced along with or later than the dolerite. In his earlier reports quoted above, Sir W. W. Smyth evidently inclined on the whole to the miners' opinion that the lode was intruded upon and cut out by the dolerite; but with the progress of the workings in the North Mine, and influenced, no doubt, also by evidence obtained about this time at Central Foxdale (p. 515) and Langness (p. 538), he abandoned this opinion; and in 1883 in describing the 30 fathom level of the new shaft he remarks that the ground was strongly invaded by dykes of dolerite, "the supposed prejudicial effect of which on the lode is, I think, not confirmed at this place, since there are parts in which a rib of this rock from 4 to 8 inches thick was flanked on either side by a branch of lode with lead and zinc ore."

We learn from the report for 1881 that in the upper level the lode was 4 to 8 feet wide, "having in places very beautiful examples of gossany lead-ore with white and green lead-ore;" and in 1883, that in the 30 fathoms the lode was difficult of definition, in places 14 feet wide, and two levels on it, though the branch usually opened on was about 2½ feet wide, mostly occupied by soft gossan with abundant minute crystals of white lead ore.

From information obtained at the mine, it appears that in these workings the dolerite was continuous southward to the end of the longest driving, 60 yards S. of the shaft; while northward it was lost, at about 90 yards from the shaft in the 45 fathom level; at 95 yards in the 60 fathom level; and at about 100 yards in the 75 or lowest gallery, probably striking off westward upon leaving the lode, with the same course that it held before intercepting the fissure, as it was not touched in the east and west cross-cuts made farther north. The dyke was disturbed and shattered in places, probably by transverse movements after its consolidation. It is not clear whether the intrusion is continuous from the South to the North mine, or whether we are dealing with separate and parallel branches. The end of the most northerly driving from the South Shaft lies about 240 yards east of the end of the most southerly driving from the North Shaft, and the character of the intermediate ground is unknown. It seems most probable that the lodes constitute

¹ MSS. in the Woods and Forests Office.

a group of roughly parallel discontinuous N.—S. fissures, and that the intrusion in traversing the tract from east to west broke across from one to the other, and followed each in turn for a short distance only. The greater portion of the metalliferous deposits appear to have been afterwards concentrated in the fissures around and a little beyond the places at which the dolerite crosses them.

In the South Mine two large transverse east and west displacements of the vein have been recognised by the miners. One of these, known as the 'Dowk Lode,' consists of a belt of crushed soft ground 66 feet broad, which sets in 15 yards north of the shaft and is said to shift the metalliferous vein 190 feet westward. The second, named 'King Slide,' occurs 130 yards north of the shaft,¹ and is supposed to displace the lode westward on the southern side. The miners' identification of their 'lode' beyond these breaks is of course open to doubt, and Sir W. W. Smyth refers to the workings north of the 'Slide,' in his report for 1875, as on "a new north and south lode at about 24 fathoms beyond the old one," and in 1880 mentions the "Blende lode," 52 fathoms east from the main lode. In Great Laxey and other Manx mines working north and south lodes, though east and west displacements, recognisable as normal faults, are not uncommon, they are never of this magnitude (p. 487).

Bellabbey or Ballasherlocke Mine.

The site of this extensive but unproductive trial is on the eastern bank of the little glen $\frac{1}{2}$ mile west of Colby (Sh. 16), 760 yards north of the main road to Port Erin, and about 700 yards east of the 'Phosphate Shaft' of the Ballacorkish Mine. The work seems at first to have been carried on in connection with the trial in the cliff at The Slock (p. 536) 2 miles farther north, under the designation of the "BELLABBEY AND FALCON CLIFF MINES." The earlier workings appear to have been the adit levels in the glen north of Bellabbey. These were referred to in Smyth's official reports for 1862 and 1869; we learn from the same source in 1870 that the adit level had been driven 87 fathoms and discovered only a string of mixed lead ore and blende 2 to 6 inches wide and a few yards in length. A shaft, ultimately attaining (in 1876) the depth of 72 fathoms, was then sunk and levels driven, mostly northward, from it at 12, 24, 36, 48, 60, and 72 fathoms, the longest being the 60 fathom which went 140 fathoms. Besides the ore in the day level above described, a little galena was found in the 36 fathom level north and in a few other places, but nowhere in profitable quantity. The supposed lode ran approximately north and south, with easterly underlie, and consisted of quartz (gossany at the top), crush-rock and 'dowk.' Water was raised from the mine by the pumps at the rate of 100 gallons per minute.² In Smyth's report for 1872, when the shaft was down 31 fathoms, it is stated that the driving had "met with a little copper pyrites and zinc blende, but scarcely any lead ore." In his report for 1876 there is the following passage:—"A very curious and exceptional little deposit of copper ore occurred in a 'warp' or loop of the vein in the 48 level north 60 fathoms from shaft; a bunch, only a few feet in length, and, as I fear, only some 9 fathoms in height, but reaching at its best 12 or 14 inches in thickness, assaying 13½ per cent."³ It is also mentioned in this report that a cross-cut at the 72 level 9½ fathoms beyond the old lode had cut another lode also dipping east but at a steeper angle. In 1880, Smyth described a cross-cut at 60 fathoms going out west for 58 fathoms without attaining any results. This appears to have been the last work done in the mine.

¹ These displacements have been indicated on the published geological map, but much exaggerated owing to the small scale of the map.

² For most of these details we are indebted to Mr. R. Barkell, the late manager of the mine.

³ MSS. in Woods and Forests Office.

to 50 fathoms, and the "lode in the 38 fathoms [south] is of good size, but valueless"; in 1863, this level had cut a slide introducing water and a better-looking lode, 3 feet of which carried some steel-grained galena, while the 50-fathom level south showed nothing of promise. The report for 1865 records the collapse of the shaft "which had been put down among old workings, and appears to have been subjected to a sudden pressure by the fall of their walls." The accident brought the operations to a close, and the failure of the mine is locally held to have been due to this cause alone; it is important therefore to note that Smyth's report for the previous year (1864) contains the opinion that "this lode has always appeared to me a hopeless blank."

The Glenchass lode has been supposed to continue its course northward to the coast between Bradda Head and Fleshwick, where it has been sought for in some small trials in the vicinity of a branching dyke of olivine-dolerite at *Lhoob ny Charran* (Sh. 15). An intermediate trial in the interior, close to the hamlet of Bradda West, known as the WEST BRADDA MINE, consists of an adit driven 24 fathoms, with a sump of 5 fathoms, on a lode striking somewhat west of north and fading east, which showed traces of blende and lead.¹ In referring to this trial in his report for 1882,² Smyth states that the lode had been tested by the old Foxdale Company 40 years previously, and expresses doubts whether it really coincides with that of Glenchass.

Castletown Harbour.

The occurrence of a little galena at this place is not only interesting as affording the only known locality³ for this ore in the Carboniferous Limestone of the Island, but also because the ore is associated, like the copper pyrites of Langness, with olivine-dolerite (Tertiary?) dykes. Cumming in 1845 described the circumstances as follows:—"This dyke has greatly altered the limestone, and more particularly in those places where it encloses a mass of limestone betwixt two of its branches. In this crystallised and altered limestone we meet with thin strings of galena."⁴ During the mining excitement in the Island some 20 years later, a small trial was begun at this place which was alluded to by Sir W. W. Smyth, in his report for 1867 in the following terms:—"At Castletown, a great cry has been made about a discovery of ore in the limestone rocks bordering the harbour. A shaft is now sinking, but in it I found no trace of vein, and it remains to be seen by driving a cross-cut from it whether anything be there on which a mine can be opened."⁵

Langness Copper Mines.

The prolonged and expensive series of trials on the western shore of Langness on some small copper veins known to Cumming⁶ in 1845 seems to have been commenced about 1875, as we learn from Smyth's report for that year,⁷ that "some strings and vein-like deposits of occasionally 2 or 3 feet in depth have been opened upon the foreshore and yielded some very good

¹ From information furnished by Mr. W. H. Rowe.

² MSS. in Woods and Forests Office.

³ There is a local belief that lead ore occurs also in the limestone at Balladoole, a little to the north of the foreshore; but the evidence offered is unsatisfactory.

⁴ Quart. Journ. Geol. Soc., vol. ii., pp. 331-2.

⁵ MSS. in Woods and Forests Office.

⁶ Cumming says, "I may also mention that along the side of the dike cutting the southern point of Langness, and in a narrow gully, I have met with fine veins of copper in the schist." Quart. Journ. Geol. Soc., vol. ii., p. 332.

⁷ MSS. in Woods and Forests Office.

copper pyrites." The work was prosecuted at various spots from that time until 1880; and after being at a standstill for a few years, was, towards the end of the decade, resumed near the southern extremity of the headland, but has since been again suspended. The strings of ore were first discovered in the Carboniferous Basement Conglomerate, but most of the workings have passed into the underlying slate. As at Ballacorkish, North Bradda and Central Foxdale, the close association of the metalliferous deposit with intrusions of olivine-dolerite lends considerable geological interest to the matter. Unfortunately in spite of the heavy expenditure of capital the total quantity of ore yet obtained has been quite insignificant—only 10 tons 18 cwt. of copper pyrites standing to the credit of the mines in the official returns ("Mineral Statistics" for 1890 and 1892). The direction of the supposed lodes is approximately north and south, with an easterly dip. The strings of ore have been found alongside or in close proximity to small olivine-dolerite dykes that fill the fissures.

The most northerly working is a small trial-pit just above high-water mark on the foreshore of Castletown Bay 420 yards N. of Langness Farm; this has a depth of 26 feet, starting in Carboniferous Limestone, and ending in dark Basement Conglomerate.

The next is a shaft 320 yards S.W. of the above-mentioned farmstead, sunk to a depth of 12 fathoms, on the raised beach near high-water mark, the upper 50 feet being in conglomerate and the remainder in slate. From the bottom a cross-cut was driven westward under the shore, at first in slate but afterwards in conglomerate, and is described as follows in Sir W. W. Smyth's report for 1876:—"This passes through mottled slaty rock beneath the Conglomerate and at thirty fathoms out has intersected the vein of 2 or 3 feet thick including a 'black stone' or trap and with some good portions of yellow copper ore in it."

The most extensive trial of the series is situated on the top of a low cliff 225 yards farther south, where a shaft has been sunk vertically in slate to a depth of 44 fathoms, with drivings westward from it under the shore. The shaft is said to have intercepted the eastward dipping lode at 30 fathoms from the surface. The lower part of the mine was flooded during my stay in the neighbourhood, but I was able in 1893 to examine a cross-cut to the lode at 12 fathoms depth, in which the junction of the slate and conglomerate was seen to occur at a small fault striking N. 8° E., and to be accompanied by a rib of intrusive dolerite like the branching dyke so beautifully exposed on the foreshore above (p. 195). Strings of copper pyrites lay along the junction of the dyke with the conglomerate, and to a minor extent at its junction with the slate. On the opposite side the ore in places permeated the margin of the igneous rock, like the lead-ore at Ballacorkish (p. 534), and was most plentiful in a bifurcation of the dyke.¹

The 40 fathom level was described by Sir W. W. Smyth in his report for 1878, as a cross-cut running S. of west for 35 fathoms in clay-slate, with short drivings along a string running N. and S. at 18 fathoms from the shaft, and along a second a little farther out having a slightly different course, both utterly barren and devoid of promise, leading to the conclusion that the bunch or two of ore in the overlying conglomerate were extinguished at this depth in the slate.

The evidence on the foreshore shows that the relation of the dyke to the lode is the same here as at Ballacorkish and North Bradda, an intrusion striking W.N.W. across the headland (p. 177) having been diverted northward for a short space by the fissure, but soon escaping from it and going off W.N.W. again. The ore in places impregnates the matrix of the conglomerate as well as the dyke-rock, and must have been concentrated in its present position either during or after the intrusion. It is important to note that both here and at Langness Point the strings of ore occur only in

¹ Our thanks are due to the engineer and captain of the mine for facilities afforded on this and other occasions.

the proximity of the dykes; at the same time, there are many more of these dolerite dykes in the neighbourhood which are not accompanied by metalliferous veins.

The course of the 'lode' of the above mine after it is abandoned by the dyke is indistinct, and does not appear to give rise here to a displacement at the surface; though it may possibly be prolonged into the sharp anticline breaking northward into a small fault which brings up the oval inlier of conglomerate among the limestones on the foreshore N.W. of Langness Farm (p. 195).

Southward of the shaft, at a distance of 200 yards, an adit has been driven into the cliff through banded slates traversed by small sheared pre-Carboniferous dykes of 'greenstone;' and 300 yards south of this again, just beyond The Arches (p. 190), there is another adit 36 fathoms long, in the Carboniferous Conglomerate.

The remaining workings are in slate at Langness Point, east of the boundary of the Carboniferous rocks. Here, on the south shore of *Port Brava* (6-inch, Sh. 19) 200 yards east of the extremity of the headland, a dyke of dolerite a foot or two wide, striking N. 8° to 15° E. along a fissure in slate, showed a string of copper pyrites along its western side. To test this, a shaft was sunk to 26½ fathoms on the ridge about 100 yards to the eastward, and a north-west cross-cut commenced to intercept the lode, but was not completed. Specks of galena were found on joint-faces in the slates of this level. A smaller pit was then sunk to 8 fathoms in close proximity to the fissure, and a short cross-cut driven from it to the dyke, but the result was discouraging. The present surface of the slate at this point is nearly identical with the ancient floor on which the Carboniferous Conglomerate originally rested (p. 191), so that the disappearance of the copper-ore downward in this place as well as in the previous workings suggests that these particular metalliferous strings tend to die out on passing down from the conglomerate into the slate-rocks.

The cliffs on the eastern side of Langness have been tested in several places by short excavations along planes of dislocation and crushing in the slate, but without revealing anything of promise.

NORTHERN HEMATITE GROUP.

Reference has been made in preceding chapters to the occurrence of hematite iron-ore in the veins which traverse the slate-rocks in the north-eastern part of the massif, and to the probability that it may indicate a former overlap of the New Red strata upon the Manx Slates in this quarter (p. 125 and p. 291). So far as is known, it is only in the north-eastern district that lodes of this mineral occur among the slates, though chalybite (carbonate of iron), and iron pyrites are abundant constituents of all the metalliferous veins, and pyrrhotine (magnetic pyrites) is also present in some places. The supposition that the hematite may, as in Cumberland, be connected with the former extension of the Triassic rocks over the area is greatly strengthened by the discovery in the deep borings in the extreme north of the Island (Chap. VII.), of Triassic rocks of considerable thickness, resting on the denuded edges of Carboniferous strata, the latter being always stained and veined with hematite.

From the conspicuous aspect of this red ore in considerable veins in the cliff on both sides of Maughold Head (p. 125), its presence must have been known in early times. As mentioned in the historical introduction to this chapter, we know that the mine at Drynane was working in the year 1700, but no particulars are forthcoming respecting the operations previous to the nineteenth century; they probably consisted of the older part of the adit-levels into the cliff, which have since been driven, at intervals, farther and farther inland. Though in the aggregate a large quantity of ore has been obtained from these mines (see Table, pp. 496-7), the output does not appear to have been sufficient, at any time of which we have trustworthy record, to meet the working expenses, and the mines have consequently been

practically abandoned since about 1874.¹ Two separate lodes or sets of lodes have yielded the chief production, the first that which traverses Maughold Head, and the second running parallel inland $1\frac{1}{2}$ miles farther westward, known as the Ballajora (Ballagorra of Ordnance map) or Magher-e-breck lode. Besides these, several minor trials have been made in the district, but all apparently without result.

Maughold Head Mines.²

On the northern side of Maughold Head, at Stack Mooar, a great vein of fault-breccia and quartz, with cavities containing hematite, strikes in a south-easterly direction across the foreshore and into the cliff, with an exposure almost equal to that of Bradda Head in size and interest (p. 125). Its width at the foot of the cliff is about 40 feet, and it fades or dips north-eastward at 15° from the vertical. The most important of the old workings at this point is said to have consisted of a deep adit-level driven in from a little above high-water mark for 95 fathoms, with cross-cuts for 5 or 10 fathoms both ways at the end, but it appears to have yielded no appreciable quantity of ore.

Better success attended another opening on the lode, known as the GLEBE MINE, about $\frac{1}{2}$ mile S.E. of the above and close to Maughold village. At this place, about 100 yards N.W. of The Vicarage, a shaft and some shallower trials were sunk, and two levels driven on the lode, the lower going south-east for 196 fathoms and north-west for 212 fathoms. This work, according to Cumming, was principally done by a company formed in 1836; and a few years later, when a Glasgow gentleman became sole lessee of the Maughold Mines, the annual shipment of hematite from the district is stated to have been about 500 tons per month,³ seventy men being employed. The south-eastward driving of the Glebe Mine appears to have passed about 100 yards to the north of Maughold Church, and if prolonged in the same direction would have emerged in the cliff above Traie Curra, close to the extremity of the headland. Hence the lode which was followed cannot directly coincide with that of the Southern or Dhyrnane Mine next to be described. Indeed, the veins of this district in spite of their apparent strength in the cliff-sections appear all to be of limited length, forming a group of impersistent converging or radiant fissures, of which those which strike towards points between north and west are more or less metalliferous.

Drynane Mine.

This term is applied to the workings on the southern side of Maughold Head, in a little inlet 500 yards east of Port Mooar (Sh. 8). As mentioned in the footnote on p. 126, the name Drynane, written Dhyrnane, is erroneously affixed on the 6-inch Ordnance map to another inlet 200 yards farther north, in which an adit has been driven to procure lumber. The Drynane Mine proper consists of a level going in from the cliff for 320 fathoms in a N.N.W. direction on a lode dipping east, with sumps on ore bodies at 10 fathoms and 37 fathoms from the entrance, and connected with a shaft from the surface at 70 fathoms. A large quantity of hematite was obtained between the mouth of the level and the shaft, but very little farther in. The chief work was done between 1857 and 1874, and is described in Sir W. W. Smyth's reports to the Woods and Forests Office, from which the following abstracts are taken. The report for 1858 states that in driving north, the level passed through two bunches of ore, the first small, but the second 8 to 10 feet wide, and capable of remunerative work; but

¹ Some exploratory work was done, on the old workings, a year or two ago, but has led to no result.

² For information regarding the old workings I am chiefly indebted to Mr. W. H. Rowe.

³ "Isle of Man," p. 311.

in the two following years we learn that no more ore had been found, though a shaft had been sunk on the vein, and a 10 fathom level driven north and south. In 1861, the adit was 95 fathoms in [beyond shaft ?], but with "no appearance of promise, although the lode is some 15 feet wide. The south level has also been advanced a long way without any farther discovery of ore. The mineral is so evidently disposed in discontinuous 'bunches' that the prospects of the mine are extremely uncertain." In 1863, the adit was 250 fathoms in, but the lode had dwindled till there was scarce a vestige of it. In 1864 we read, "On careful examination I saw that the drift was really carried on in the lode, and that it occasionally formed a vein of a foot or two in width, but utterly valueless." The later reports contain only passing reference to the workings, until 1873 when it is noted that a long way in the old level and to the east of it, on climbing a rise some 7 fathoms up, a rib of ore of minor importance was seen, "not to compare with the old deposits worked away years ago."

The UMBER Mine level mentioned above, which was last in operation between 1887 and 1893, appears to be driven on a decomposed dyke of olivine-dolerite having the usual north-westerly direction. On a plan in the possession of Mr. W. H. Rowe this is shown as intersecting the Drynane level a short distance from its northward termination, with indications that the dyke may have slightly displaced the lode. It is to be regretted that no further evidence is available as to their relations.

Ballajora Iron Mine.

These workings, from which a fair amount of hematite was marketed, were carried on between 1858 and 1874 on N. and S. lodes, dipping eastward, close to the farmstead of Margher-e-breck (*Magher* - of old one-inch Ordnance map, *Mangher* of new) in the parish of Maughold. There are two old shafts N. of the farm, one said to be 18 fathoms and the other about 30 fathoms deep, in the vicinity of which the chief bodies of ore were found; an adit connected with these workings has its mouth in a cross-cut 250 yards S. of the farm. The lode seems to have been very irregular, and in its northern portion to have consisted of two branches.¹ A few descriptive details have been gleaned from Sir W. W. Smyth's reports, as follows²:— In the report for 1859 it is mentioned that the lodes called No. 1 and No. 2 have proved large and capable of yielding a fair return of iron-ore, but "unfortunately a great proportion of this is carbonate of lime and iron yielding a percentage of iron [too small] to bear the expense of carriage." In 1861, the No. 1 level had been driven a long way "in a large lode of impure carbonate of iron," while "the 'School-house lode' has yielded some few cargoes of first-rate hematite, but where hitherto opened, averaging from 1 to 2 feet wide, is not large enough to insure a remunerative mine." In 1872 ("Ballajora and Maughold Head Iron Mine") it is noted that the adit level in the S. ground had opened in a new lode when 20 fathoms in and showed "2 to 5 feet wide of a fair quality of hematite"; and in the following year "two stopes and a sink below the adit" are mentioned in these workings which soon afterwards fell into abeyance.

Other trials for iron-ore, regarding which little or no information has been obtained, are indicated at several places in this neighbourhood; on the N. side of the Smithy at Ballasaig there is a large spoil heap, marked "Iron Mine" on the 6-inch map. (Sh. 5); similar though less conspicuous traces exist in a field 250 yards S.E. of the Wesleyan Chapel at Ballagorra; 350 yards N. of this chapel is the obliterated mouth of a level which was driven for 100 yards into the hill-side; and another level, marked "Iron Mine" on the 6-inch map opens into the cliff 500 yards S. of Gob ny Garvain. (See List at p. 552.)

¹ The above information has chiefly been obtained from Mr. W. H. Rowe.

² MSS. in Woods and Forests Office.

MISCELLANEOUS TRIALS.

Abbey Lands Mine.

This designation was applied to a trial made between 1865 and the banks of the tributary to the River Glass known as the *Sul* 1,150 yards N.N.E. of the bridge at Abbey Lands (six inch, St consisted of a shaft with drivings, on the east bank of the stream short adit on the west bank. Smyth mentions it in his report for 1 "sinking on a lode coursing north-east." The supposed lode is the belt of crushed ferruginous slate still to be seen in the bed of a few yards above the ruins of the mine. In his report for 1867, authority states that there was a single driving east at 28 fathoms containing calc-spar and copper pyrites; in 1868, we learn that was idle, but a trial adit 100 fathoms farther south showed another better character but with no metallic substances; in 1869, a 27-fathom was being driven west to cut this (north-and-south) lode; in 28-fathom level had been driven 40 fathoms on a lode north-west which 13 yards in length had been slightly ore; in 1871, when the 27-fathom south level was driving, Smyth refers to "the obscure character of this piece of ground"; in 1872, the 27-fathom had apparently intercepted the second vein mentioned above, which to be a large lode but with no metallic substances of any value work was then stopped. In reporting on a proposed assignm lease in 1883, Sir W. W. Smyth stated: "I have on several examined these operations underground, and never yet saw any promising character, or that would give ever so small an amount of saleable ore."²

Ballaglass or Great Mona Mine.

Large sums of money were expended upon this trial of a small and-south lode discovered in the bed of Cornah River 1,050 yards high road from Ramsey to Laxey. The workings commenced about and in 1857 Sir W. W. Smyth reported that much spirit was being in driving the 10 and 24 fathom levels, on a vein with small quantities of copper, zinc and lead, but too narrow to warrant much further work. The same year there is a record of 9 tons of lead ore and 8 tons of zinc the credit of the mine in "Mineral Statistics," which appears to be return made from it. The mine was then suspended for some years restarted by the Great Mona Mining Co. in 1866, with no better result. In 1867, Smyth noted that a few stones of ore had been raised; and that the shaft was down to 50 fathoms, with no improvement. It appears to have been the depth attained when work was abandoned. The lode is said to have been nowhere more than 6 to 12 inches wide but have had an easterly underlie. A small uncrushed igneous dyke of character traverses an E.-W. joint or small fault in the slaty slate immediately to the westward of the mine (see p. 140), and must be in by the lode. An intrusion of different character has been encountered in the workings, as shown by the fragments of sheared granite contained in the spoil-heap.

Ballaskeg Mine.

The Great Mona Company also drove two levels (the longest 60 or 70 fathoms) into the cliff 700 yards N. of Port Cornah, on a W. lode containing traces of copper ore, which were known as BALLASKEG MINE. Another level was driven, equally unprofitable, on the side of the valley near Corany Bridge.

¹ MSS. in Woods and Forests Office.

² *Ibid.*

Barony Mine.

This name was given to a small trial for copper made many years ago on a conspicuous N.—S. lode exposed on the foreshore 200 yards S.W. of Port Cornah, as described in a previous chapter (p. 129). The shaft, on the low cliff, is said to have been sunk 15 fathoms, and a level driven S. from it at 10 fathoms, until stopped by water, on a good gossany westerly dipping lode with some carbonates of copper. A cross-cut adit was afterwards driven from Port Cornah.¹

Baldwin Mine.

This old mine, the site of a long and obstinate trial with the most meagre results, is located on the east bank of the River Glass opposite the hamlet of Baldwin. A plan of the mining sett in the Woods and Forests Office, dated 1864, shows two parallel lodes, "No. 2" and "No. 3," 40 or 50 yards apart, striking approximately N.N.W., intersected by other two ("No. 1" and "Wheelcase Lode") similarly parallel and the same distance apart, striking E.—W., but these lodes were probably more or less imaginary. From the papers accompanying this plan, it appears that a level had been driven in the first instance by the Isle of Man (Foxdale) Mining Company, and abandoned. Later, sometime between 1850–55, an attempt was made by other parties to sink a shaft; and finally, in 1862, a lease was granted to the "Baldwin Mining Company, Limited," and work commenced in earnest. In 1873, we find it stated that about £20,000 had been expended, and ore sold to the value of £168 3s. 3d. only, with some 5 or 6 tons more at the surface partially unwashed. Sir W. W. Smyth's reports contain many details of the workings. In the report for 1863 we learn:—"From the bottom of the shaft, now 17 fathoms deep, a cross-cut is driving N. and S. to intersect the three veins which have been seen at the surface. The southern one is without promise, but the ground looks more favourable in the direction of that lode which at a shallower level had last year yielded some large lumps of lead-ore." In 1867 the shaft was 66 fathoms deep, with drivings; in the 42-fathom S. level a little ore had been obtained on the hanging side. In 1868 the 42-fathom level was out no less than 140 fathoms from the shaft; and "one little course of ore is yielding lead and blende ores, rather in cwt. than in tons" and hardly worth the timbering. In 1870 the 66-fathom level on No. 2 lode is mentioned as having for about 14 fathoms yielded a fair amount of ore, but improvement was still needed. In 1871 a winze had been sunk 11 fathoms, and about 12 fathoms of a 77 fathom level driven "unfortunately finding only poverty beneath." The following year we learn that the capital of the company was exhausted.

Ohio, otherwise East Baldwin Mine.

The ruins of this mine may be seen in the East Baldwin valley on the east bank of river 50 yards north of the mill at Ballawyllin. It seems to have been commenced in 1866, and furnishes another example among Manx mines of long and costly working with the most insignificant result. It is mentioned in Smyth's report for that year as "a small shaft sinking on a not very pronounced vein," and reference is made in the following year to the unwarranted excitement in Douglas over a surface-discovery at the mine. In 1868 Smyth notes that a 10-fathom level showed the "lode of a very confused and ungainly appearance," and that no ore whatever was being raised. In 1869, the mine was down to 35 fathoms, "but there is here a junction of veins with an exceedingly puzzling piece of ground to unravel . . . a little good ore had been met with in one place for 2 or 3 fathoms in length," in the 25-fathom level. In 1870, the lode was being cut in the 50-fathom level, but the little ore obtained was from a sump in

¹ From information obtained from Mr. W. H. Rowe.

the 35-fathom level, "which is the only exception to the mass of confused and broken black ground." In his next report Smyth states that the mine was sunk to 60 fathoms, and that a level at 50 fathoms was 25 fathoms long "with nothing of promise till close to the end, where came in a favourable looking branch of zinc-blende." In 1872, with the shaft at 70 fathoms, it is noted that much driving had been done, "but with the curious result that neither the E. and W., nor the N. and S. lode can be found ore-bearing except in the one limited bunch" previously recorded; and in 1873, the 70-fathom level had been driven some fathoms east and west "in black slate country, and showing not a spark of any useful mineral," while the 60-fathom level was driving north on a N.-S. lode, but without a trace of ore. After which it is not surprising to read in the following year that the mine had stopped. It was restarted, however, by "The Manx Silver-lead Mining Company, Limited;" and Smyth noted in 1876 that a little ore had been scraped up in the 36-fathom level from the skirts of the original bunch; and in 1878, that the shaft was down to 92 fathoms, and that it was intended to carry it down to 104 fathoms—an intention which does not appear to have been fulfilled.

The only returns from this mine published in "Mineral Statistics" are in the years 1872, 1874, and 1875, the total amount being 24½ tons lead ore and 39 tons 8 cwt. zinc-blende.

Douglas Head Mine.

Some utterly profitless mining work was done on Douglas Head (Sh. 13) between 1865 and 1871, consisting of a long adit driven in from the cliff at the southern side of the headland, and a shaft on the summit S.W. of Fort Anne Hotel. The character of the operations will be understood from the following extracts from Sir W. W. Smyth's reports:—In 1865 the report states that "a shaft had been sunk for 14 fathoms, and a couple of fathoms driven on a lode coursing N.E. and S.W. with 'umbery' gossan, but no appearance of ore; while a cross-cut adit was driving from 'Billy Gilbert's harbour,' which will have to be pushed from 60 to 70 fathoms in order to meet an expected lode." In 1866, the level driving in from the sea had "no appearance whatever of a promising character"; in 1868, it had a length of 80 fathoms in hard ground [Lonan Flags] costing £13 to £16 per fathom, "the vein a mere string without a speck of mineral in it the whole way"; and in 1870, the shaft had been sunk "24 fathoms on a course termed a lode but having a very problematical appearance and not a grain of any kind of ore."

Ellan Vannin Mine.¹

Under this term an unproductive trial was made between 1870 and 1875 in the little glen locally known as Cartwright's Glen, which joins Glen Auldyn south of Skyhill farm. The workings were commenced on the strength of the discovery of lumps of lead-ore in a gossany north-and-south vein in the bed of the stream, which it was thought might be the prolongation of the Laxey lode. The favourable indications disappeared however in adits driven north and south on the lode. A level was then driven from the bottom of the valley 200 yards lower down, below the bend of the stream, to cross-cut the lode under the hill. This is said to have attained a total length of 104 fathoms, with branches. Sir W. W. Smyth notes in his report for 1874 that the long level failed to show the least sign of any vein on which to open workings. A shorter level, 30 fathoms long, driven north-north-westward from the fork of the streams due S. of Skyhill, to test another supposed lode known as the Douk Vein, was equally unsuccessful. The cost of the trials must have been considerable, and no ore was marketed.

¹ From plans and information furnished by Mr. W. H. Rowe.

Glen Auldyn Lead Mine.¹

This name was given to a series of trials in the upper part of the picturesque glen which falls into Glen Auldyn from the east at Balleigh-crach (six-inch, Sh. 5). The earlier workings in the ravine, 500 yards west of the mountain road below North Barrule, consisted of sinkings and short levels on a vein striking N. 20° E., with a westerly dip. A dyke of olivine-dolerite (described on p. 136) is intercepted by the supposed lode at this point, but I have not been able to obtain definite information as to their relationship. A deep adit-level was afterwards started 200 yards lower down the valley, to cross-cut the lode; and was driven 69 fathoms, but is said only to have cut the 'flookan,' a subsidiary vein, and not the main lode. Sir W. W. Smyth refers to the workings in his report for 1866, describing the vein as a "soft lode on which adits are driving . . . with small isolated stones of lead ore." No returns of ore were made.

In another branch of the same glen, 400 yards west of the above, at the place marked "Lead Mine" on the six-inch Ordnance map (Sh. 5), there is an old working regarding which no information is forthcoming; it appears to consist of a level driven south, but no lode is visible.

Glen Crammag.

An old adit may be seen in the east bank of this glen, 300 yards above its junction with the Sulby River (Sh. 7). It goes E. 20° N. on a dislocation at the margin of the "crush-conglomerate," the "lode" consisting of crushed slaty pyritous fault-stuff and quartz. This is probably the working mentioned by Smyth in his report for 1866 as being on a "very unpromising great dowl lode."

Glenfaba Trial.

Respecting the working on the south side of the Neb about 100 yards N. of Raggatt, Smyth reported in 1858, "a level has been driven a few fathoms from near where the road, at one mile south of Peel, crosses the river, but there is no lode at all."

Glen Meay or North Foxdale Mine.

A plan of metalliferous veins at 'Glen May,' dated 1826, is preserved in the Woods and Forests Office, showing two north and south "main veins," and three N.W.—S.E. "cross-veins" or "feeders," with the note—"The whole of these veins, laders and feeders bear lead ore to the surface, and are in every way promising to be productive in that metal." The workings afterwards carried on, chiefly between 1857 and 1865, were situated 550 yards from the shore, or 150 yards higher up the glen than the position of the veins as shown on this plan which, however, may have been incorrect in scale.

In Sir W. W. Smyth's reports for 1858 and 1869 it is stated that small portions of ore were visible in the workings, but no appearance of a regular or strong vein. In 1861 we learn from the same source that drivings were being prosecuted "at 15 fathoms deep, in two lodes running pretty distinctly through clay slate and from 6 inches to 2½ feet in breadth, but unfortunately yielding no ore; traces of iron pyrites and carbonate of iron being all the metalliferous matter present." In 1866, "favourable stones of lead ore have been met with at various points, but not continuous enough to be of value." In 1866, a 14 fathom level had been driven a great many fathoms east to no purpose, as well as a cross-cut north; while "a short cross-cut south on the extreme west of the workings has laid open a very

¹ Information chiefly furnished by Mr. W. H. Rowe, to whom I am indebted for a copy of a mining plan of the locality.

promising appearance of lead ore, at the rate of several cwt. of ore to the fathom." In 1867, it is stated that in the last 3 fathoms of the shaft the vein had yielded stones of lead to make up 3 or 4 tons. In 1868, the workings are described as a 50-fathom inclined shaft, and a driving of 3 fathoms. In 1869, we learn that the 50-level had been driven 70 fathoms west and 30 fathoms east on an unkindly lode yielding nothing whatever; and this is the last mention of the mine in these reports.

Glen Rushen and Niarbyl (Isle of Man Antimony Mining Company).

In an old trial made about the middle of last century on the shores of Niarbyl Bay in search of the westward prolongation of the Foxdale lode, a small body of antimony ore (*antimonite*) was discovered. As it was currently believed that more of this ore might at that time have been obtained if it had been considered worth working, the ground was reopened in 1894 by an adit driven eastward into the cliff at Traie Vrish (Sh. 12), 400 yards S.E. of The Niarbyl, only to find that the ore-body had been merely a small pocket which had been entirely cut out in the previous workings.¹ Specimens of the ore may still be obtained from the old spoil heap at the foot of the cliff at this place. It is apparently the only occurrence of this mineral in the Island.

A renewed attempt was made under the same auspices to discover the Foxdale lode in Glen Rushen, west of Beckwith's Vein (p. 504), but without success.

Injebreck Mine.

Under this name a trial was made between 1872 and 1876 in the valley of the head-waters of the River Glass, 300 yards N.E. of Injebreck House, at the place marked *Lead Mine* on the six-inch Ordnance map (Sh. 10). Smyth described it in 1874 as consisting of a shaft 22 fathoms deep, with a bit of level east and a cross-cut south, revealing mere specks of ore of no value.

Kerroo-Mooar Mine.

This rather extensive mining trial was made between 1860 and 1870 in the steep bluff of slate at Kerroo Mooar, nearly a mile to the eastward of the village of Sulby. It consisted of three levels driven, one above the other, southward into the hillside on a somewhat uncertain 'lode' striking nearly due south with an easterly underlie. The lowest level was about 100 fathoms in length; the second 80 fathoms; and the highest 50 fathoms; the vertical distance between the first two being 16 fathoms, and between the last two, 10 fathoms. In the two upper levels a little galena and blende, associated with barytes, was discovered, but not in marketable quantity. The lowest level for several fathoms from its entrance was in the boulder clay, which is banked thickly against the foot of the slope. The workings intercepted one of the olivine-dolerite dykes, and a shallow sinking on the dyke is said to have revealed; a little galena on the 'foot-wall' of the intrusion.² In an adjacent open quarry, as described on p. 59, one of the older 'greenstone' intrusions is worked for road-metal, and a thin dyke of olivine-dolerite, probably a 'flier' from the dyke found in the mine, is seen to traverse both the country-rock and the 'greenstone.'

Information supplied by Mr. Bawden, the manager of the recent workings.

² We are indebted to Mr. W. H. Rowe for most of this information.

Sir W. W. Smyth mentioned the operations in his report for 1866 as 'a promising vein being driven on, but without farther discovery of ore;' and in 1867 noted that "a good deal of veinstone containing lead and zinc ore has been brought to the surface, but none yet dressed"

Kirk Michael Lead Mine.

References to preliminary operations in this locality are contained in Sir W. W. Smyth's reports¹ for the years 1858, 1859, 1860, and 1861, but the chief work on this small mine was effected at intervals between 1868 and 1883. Its total yield as given in "Mineral Statistics," between 1870 and 1883 was 222 tons of lead ore. It is situated in the deep glen which lies between Slieau Curn and Slieau Freoaghane, about 1½ miles S.E. of Kirk Michael, and furnishes the only known example of a metalliferous vein in the north-western district of the Island. The direction of the lode seems to have been about W. 40° N.—E. 40° S., with a north-easterly underlie, but after being traced for 120 yards it was lost in both directions, apparently through cross-faulting, being intercepted by east to west slides, known respectively as "the Great Douk vein" on the S.E. and the "Cross lode" on the N.W. The mine was worked by three day-levels driven into the hill to intercept the lode, and by a shaft. Other trials were made on the steep slopes on both sides of the glen, but with no result.² In describing the workings on the productive part of the mine in his report for 1875, Smyth notes that in the No. 2 level, S. of the cross-cut, a shaft had been put down 6 fathoms, with drivings north and south from it, the lode 2 to 3 feet wide "consisting of two small strings of galena with killas between them, and yielding at most 8 or 10 cwt. of ore per fathom." We are informed that over £10,000 was expended on this property.

Laurel Bank and Wheal Michael.

In his report for 1863 Sir W. W. Smyth refers to a working of this name carried on by Mr. Ashe "in some singularly contorted 'country' in which were some irregular floors of quartz sparsely containing delicate stars of a rare nickel-mineral, 'Millerite,' but there was no lode at all." In his "List of Manx Minerals" (Isle of Man Nat. Hist. and Antiq. Soc., vol. i., p. 147) the same authority mentions the mineral as "delicate capillary crystal vein-stuff at a trial shaft at Rhenas, south of Kirk Michael." It is not easy to identify this locality; Laurel Bank is given on the 6-inch Ordnance map, Sh. 9, as the name of a house on the western side of the Neb Valley one mile below Glen Helen; Rhenas is two or three miles higher up the same valley just above Glen Helen. There are traces of a small mining trial between these places, 500 yards south-west of Lambfell Mooar, in the little gully which joins the Neb Valley just below Glen Helen; but Mr. Ashe's trials seem chiefly to have been carried on, under the title of the WHEAL MICHAEL MINE, on the hill named Cronk ny Fedjag, about a mile north of Rhenas, where the traces of a shaft and other workings may still be seen. Either of these localities may be the place referred to by Smyth, but the former is the more probable. An old plan of the Wheal Michael mine in the possession of Mr. W. H. Rowe shows two supposed lodes; one coursing east-north-east, on which the shaft is sunk; and another, coursing north-north-east and intersecting the first, which was tested by a short level in Glion Cannell, 150 yards north of Shughlaigquiggin. Both lodes are said to have yielded samples of lead ore. An older working, apparently of greater extent but respecting which no information is forthcoming, occurs a little farther east, on the banks of the stream 350 yards north of Cronkbane Farm, in the vicinity of a mass of intrusive "greenstone" (p. 137); this is marked "*Lead Mine (Disused)*" on the six-inch map (Sh. 6).

¹ MSS. in Woods and Forests Office.

² The above information has been furnished by Mr. W. H. Rowe.

Maughold Head Copper Mine.

This working, erroneously marked "*Lead Mine*" on the six-inch Ordnance map (Sh. 5), consists of an adit, stated to be 60 fathoms long, driven into the cliff on the south side of Gob ny Strona, the most easterly point of Maughold Head, on a dolomitic vein containing a little copper pyrites, striking in a west-north-westerly direction. Sir W. W. Smyth referred to it in his report for 1866 as "a lode 3 feet wide, promising in appearance, but in a place very difficult of access"; and in 1867 he mentioned that a shaft had been sunk for 10 fathoms at the base of the cliff where the ore appeared to be cut out. The trial was abandoned without having produced any marketable ore. (Since this was written, work has been resumed here, the shaft deepened, and a level at 18 fms. driven towards low-water, where the lode is reported to widen out.)

Montpellier Mine.

This was a trial made about 1866 in the ravine of the western feeder of the Sulby River under Sharragh Bedn (Sh. 7) 600 yards N. of Croit. A line of disturbance and faulting traverses the slates in this glen in a W.N.W. direction, hading northward, which may have constituted the 'lode.' Some lumps of lead-ore are said to have been obtained, but nothing of permanent value; one of the levels is stated to have gone about 50 fathoms. Sir W. W. Smyth described it in his report for 1866 as "a level driven and shaft sinking with nothing to recommend it."

Mount Dalby Silver-Lead Mining Company, Ltd.

Under the auspices of this company some trials were made near Dalby about the year 1872 in the valley of the Lagg River, half a mile east of Barrane, but without attaining any useful result. Sir W. W. Smyth, in October 1872, after examining these workings, reported that "of the favourable appearances. . . not a trace exists," and that the only facts were that the sett contained vein-like traces, in which no ore had yet been found, in the direction of the Foxdale lode. The statements which were made in the prospectus of this company must be read with astonishment by anyone knowing the ground.

Onchan (Douglas Bay) Mine.

This working, which appears in the list of Manx Mines in "Mineral Statistics" for 1891 and the succeeding years, consists of a sump and an adit in a direction of N. 10°—20° W., in the slate cliff on the northern side of Douglas Bay, 200 yards west of Derby Castle. From an account published in the "Transactions of the Manx Geological Society, Session 1891-92" (reprinted from "Mona's Herald" newspaper, 6th January, 1892), it appears that "a piece of almost pure plumbago was found upon the shore within a very short distance of the place," and the working seems to have proved the presence of that mineral in the lode. In the same account it is stated that "the adit so far shows a lode containing quartz, lead, baryta and oxide of iron, though as yet only in moderate quantities." A later newspaper report announced that ore had been found containing several pennyweights of gold per ton, but the discovery does not appear as yet to have assumed any economic importance.

Pen (Beinn) y Phot or Sulby River Mine.

The insignificant trial thus named consisted of a level and shaft (marked on the 6-inch map, Sh. 7) on the west bank of the headwaters of the Sulby River, one mile S.W. of the summit of Snaefell. Considerable sums must have been expended on the erection of a large wheel and other surface works, the ruins of which are still conspicuous. Sir W. W. Smyth refers

to it in his report for 1866, as "on a north and south lode, dowky or with soft clay"; and in the following year mentions that it was started with fine plans, and then heart lost. In a later communication to the Woods and Forests Office (Sept., 1881), he remarks that no conclusive trial was ever made at this place.

The Ramsey or Northern Mine.

This trial, on which some thousands of pounds were expended, was made between 1866 and 1873, on a small north and south vein containing a little galena and blende, in the slate cliff at Gob Ago (Sh. 5) on the eastern side of Port e Myllin (*Vuyllin* of revised Ordnance map). The first workings consisted of an adit driven for about 50 fathoms southward on the lode; a shaft was afterwards sunk (26 fathoms l) and a driving under the sea northward commenced, where it was expected the vein would intersect the course of the broad belt of felsitic igneous rock exposed in the cliff 500 yards farther eastward (see p. 124).¹ No further discovery of ore was made however, and the total quantity produced was too small to be worth marketing. Another old level, a few fathoms in length, exists in the eastern corner of Port e Myllin 200 yards west of the above.

Sir W. W. Smyth makes brief mention of this trial in several of his reports.² In 1866 he notes there was "nothing more met with than pretty strings 1 to 3 inches wide with good galena"; in 1867 he refers to it as "a tempting vein of lead ore, but far too small to be important." In 1871, the shaft had been sunk 21 fathoms and was intended to go 5 fathoms deeper; in 1872, a cross-cut was being driven out; and in 1874, the mine was "idle."

NOTES ON OTHER VEIN-PRODUCTS.

Gold.

From the general character of the Manx Slates and some of its veins, it is not inherently improbable that a little gold should be found in the Isle of Man; but the evidence for its presence is, as yet, scarcely satisfactory. In 1867 D. Forbes in describing the occurrence of polytelite in the Foxdale Mine mentioned that the Foxdale granite is identical in composition with some auriferous granites, and that traces of gold were reported to have been found in the gullies and in quartz-veins contiguous to it.³ Capt. J. Kitto, late of the Foxdale Mines, informed me that he also had heard that specimens of gold had been found, some time ago, in this district, but had not himself seen them.

Among Cumming's geological specimens preserved in King William's College at Castletown, are two water-worn fragments of slate showing specks of free gold, in the one specimen on a smooth cleavage face, and in the other in a crushed vein-streak. An almost illegible label on one of the specimens appears to read "Langness," and the rock is of the kind which occurs in that locality. The reported presence of gold in a vein mined on the northern side of Douglas Bay has been mentioned on p. 548⁴.

¹ From information and plan furnished by Mr. W. H. Rowe.

² MSS. in Woods and Forests Office.

³ "Researches in British Mineralogy." Phil. Mag., 4th ser., vol. xxxiv., p. 354.

⁴ A note of this supposed discovery appeared in "Nature" of Jan. 24th 1895, vol. li., p. 299.

The metal is not included in Sir W. W. Smyth's published list of Manx Minerals.¹

Since the above was written a small trial has been made near the Cluggid in Sulby Glen on a vein reported to contain gold; and another trial at Maughold. Both are however now suspended. (Aug., 1902).

Molybdenite.

This mineral occurs as a thin incrustation on joint-faces of the Dhoon Granite in the quarry on the west side of the high-road, half a mile north of Dhoon Glen, where, according to Smyth, it was mistaken for lead ore.² It has not been observed elsewhere in the Island.

Plumbago.

The presence of graphitic slate at two or three localities in the Manx Slate Series has been noted in a previous chapter (p. 94 and p. 134). No workable deposit of the mineral has yet been found in the Island. In Sir W. W. Smyth's "List of Manx Minerals" (op. cit., p. 143) graphite is recorded as occurring "impure in the Snaefell Lode 100 and 130-fathom levels"; and in some handbooks of Mineralogy (*e.g.*, that of Greg & Lettsom, 1858, p. 2), "Beary in the Isle of Man" is given as a locality for the mineral. Documents in the Woods and Forests Office throw light upon the last-mentioned reference. From these it appears that in 1852 leave was granted to the Rev. J. G. Cumming and Dr. T. Underwood to search for manganese and other minerals in the parish of German, east of the Neb and north of the Peel and Douglas highroad, and that "in the course of their searches they have discovered some plumbago, which they wish to have included in their licence," which was accordingly done. In February 1854, the resident Crown Agent reported that a day-level had been driven about 25 feet in this sett, with a side-cut to meet the opposite cheek of the vein; and that about 40 tons of raw stuff had been raised, but the samples were not sufficiently good in quality to command the attention of plumbago merchants and no sale had been effected; strings of copper had also been observed in the district. The site of this working appears to have been on the slope of Beary Mountain, but the exact locality has not been identified; Cumming no doubt refers to it in his "Guide to the Isle of Man" (1861, p. 27), where he states, "Plumbago has been discovered in Glen Helen."

The discovery of a piece of plumbago of good quality on the foreshore at Douglas, derived from a neighbouring lode, has already been mentioned (p. 548).

In connection with this subject the occurrence, under circumstances previously discussed, of a singular string of anthracite in the Laxey mines should not be forgotten (p. 520).

¹ Op. cit., p. 146.

² *Ibid.*

**LIST OF SMALL MINING TRIALS NOT DESCRIBED IN THE
FOREGOING PAGES.¹**

Sheet of 6 inch Ordnance Map.	Locality and Position.	Description of Working.
Sheet 4.	Hillside S. of Ballaugh, 400 yds. W. of <i>Corn Mill</i> ²	Small shaft
	Glen S.W. of Sulby, in gully 400 yds. N.E. of Earykellue	Short trial along fault
	Glen S.E. of Sulby, in bank of stream 600 yds. S.S.E. of Ballamanaugh	Short adit going E. 15 N.
Sheet 5.	Steep slope 300 yds. S.E. of Glentramman East, marked <i>Lead Mine</i> on 6-inch map	Adit; stated to go 8 or 10 fathoms on an E.-W. "douk-lode"
	Near stream 700 yds. S.W. of Parkneakin	Small sinking on "douk-lode with spots of lead"
	Cliff 300 yds. W.N.W. of Port Lewaigue	Short adit
Sheet 7.	<i>Glen Shoggle</i> , 120 yds. S.E. of Nascoin	Adit into south bank of stream
	Stream 400 yds. E.S.E. of Stockfield	Adit into west bank (? part of <i>Wheal Michael</i> workings; see p. 547)
	W. slope of Sartfell, 900 yds. S.E. of Barrowgarroo Beg	Adit, marked " <i>Lead Mine</i> " on 6 inch map, but probably a slate-trial
	Head of <i>Glion Kiark</i> , S. of Slieau Freoaghane	Level in connection with slate-trial
Sheet 8.	Head of Glen Auldyn at slate-trials at upper fork of streams	Two levels (? for slate), marked on 6-inch map
	Head of Cornah Glen, between <i>North Laxey Mine</i> (p. 524) and <i>East Snaefell</i> trial (p. 526)	Adit in north bank marked on 6 inch map
	Cornah Glen, S. slope, 1,550 yds. W. of Corransy	Adit on hill-side marked on 6 inch map.
	Cornah Glen, S. slope, 1,100 yds. S.W. of Corransy	Adit near top of slope.
	Cornah Glen, in gully 150 yds. S. of Park Lewellyn	Short adit, E. 15 N.
	Cornah Glen, N. side of stream 200 yds. W. of Corransy	Adit 40 fathoms long, on a well-marked lode without ore
	Cornah Glen, S. slope, 250 yds. S.E. of Corransy	Small shaft; hematite-stained slate in spoil-heap
	E. bank of small stream, 250 yds. S.W. of Boileylvelt	Small shaft?; spoil-heap of hematite-stained slate

¹This list represents the old trials noted on the working map during the Survey, respecting which no information was forthcoming. It does not profess to be exhaustive, as there have no doubt been many other trials of which there are now no distinct traces. It is intended to illustrate the extent of the exploratory work.

²Distances given as measured on the 6-inch map; place-names in italics will be found on the 6-inch map, but not on the 1-inch.

Sheet of 6 inch Ordnance Map.	Locality and Position.	Description of Working.
Sheet 8 (cont.).	Ballasaig, 200 yds. W.S.W. of <i>Smithy</i> , and again 50 yds. N. of <i>Smithy</i>	Small shafts (trials for hematite)
	Ballagorra, 400 yds. W.S.W. of Chapel at cross-roads	Small shaft
	Ballagorra, 350 yds. N. of Chapel at cross-roads	Adit, "50 fathoms long" (see p. 541)
	Ballagorra, 250 yds. S.E. of Chapel at cross-roads	Small shaft (obliterated)
	Cliff 500 yards S.W. of (Job ny Garvain	Short adit N. 15. W.; marked <i>Iron Mine</i> on 6-inch map (see p. 127)
	Cliff at Bulgham Bay, 300 yards S. of Dhoon Mine adit (see p. 528)	Short adit
	Dhoon, in small ravines east of high road.	Several short adits in granite, for 'polishing powder' (see p. 556)
	Head of <i>Glion Ruy</i> (Glen Agneash)	Adit (and shaft ?) marked <i>Lead Mine</i> on 6 inch map
	Glen Agneash	Several workings in search of N. prolongation of Laxey lode (see p. 523)
	Laxey Glen, east bank of <i>Stroan ny Fasnee</i> .	Adit N. 25 E.
	Laxey Glen, west bank, 150 yards above <i>Mill</i> .	Adit, starting in till
	Laxey Glen, lower part.	Several workings in search of S. prolongation of Laxey lode (see p. 521)
Sheet 9.	Cliff S. side of White Strand.	Adit along small fault in Peel Sandstone
	<i>Cass Stroan</i> , 150 yards inland.	Shaft in Peel Sandstone (see p. 274)
	N. corner of field 350 yards E.N.E. of Lambfell Mooar.	Spoil heap, small sinking ?
	Cliff 300 yards S. of Glen Meay.	Adit
	Gordon, 500 yards W. of high road.	Adit (and sinking ?) marked <i>Lead Mine</i> on 6 inch map
	Ballacoshnahan, near W. margin of valley 700 yards S. of <i>Ash Lodge</i> .	? small sinking
	N. slope of Slieau Whuallian, 300 yds. S.W. of Glen Aspet	Small shaft
	N. slope of Slieau Whuallian, 300 yds. S.E. of Glen Aspet	Adit in connection with slate-trial
	Lower part of Foxdale, west bank, 550 yds. E. of Slieau Whuallian Farm	Adit S.W. through till into slate
	Lower part of Foxdale, in small gully, 400 yds. E.S.E. of Sheau Whuallian Farm	Adit: marked <i>Lead Mine</i> on 6-inch map.
	West side of road at Ballacates	Adit
	Slope 800 yds. N.N.E. of Ballagaraghan	Obscure spoil-heap ? : graphite-trial ? (see p. 550)

Sheet of inch distance Map.	Locality and Position.	Description of Working.
Sheet 10.	S. side of glen N. of Carn Gerjoil, in N.W. corner of field 200 yds. N. of mountain road	Obscure spoil-heap, probably adit
	Hillside S. of Greeba, 300 yds. W. of <i>Creg y Whualliam</i>	Spoil-heap : shaft or adit
	N. side of <i>Cooulingill</i> , 500 yds. S. of <i>Creg y Whualliam</i>	Shaft (see p. 518)
Sheet 11.	N. branch of Glen Roy, 350 yds. E. of Ballaquine	Adit E. 30 N. into bank of stream
	Cliff, 750 yds. S. of Laxey Harbour	Adit
	Cliff, 1,150 yds. S. of Laxey Harbour	Adit N. 10—20 W.
	Cliff, Garwick, on S. side of Glen	Adit, now called a cave
	Cliff, Garwick, 150 yds. S.E. of above	Adit, now called a cave
	<i>Glen Gawne</i> , Garwick, S. bank 350 yds. W. of shore	Adit and cross cut
	<i>Glen Gawne</i> , Garwick, S. bank 100 yds. W. of tram-line bridge	Adit S. 30 W.
Sheet 12.	Head of middle fork of glen east of Ballelby, near Dalby	Small trial (adit ?)
	Cliff on S. side of <i>Gob ny Gameren</i>	Small trials
	<i>Glionn Maarliagh</i> , 600 yds. E.N.E. of Ballavell, Glen Rushen.	Short adit
	Glen Rushen, W. side, in gullies 300 yds. N. of Glionn ny brack	Short adits (see p. 546 for other workings)
	Glen Rushen, in banks N. of high-road bridge	Short adits
	500 yds. N.W. of South Bar-rule Quarries	Adit in connection with slate-trial
	<i>Beeal-seayn-ny-Geay</i> , S.W. side of Cronk ny Arrey Lhaa	Adits along faults
	Summit of Cronk Fedjag	Adits in connection with slate-trials
	Gully 250 yds. N.E. of Garey Mooar	Adit along decomposed olivine-dolerite dyke (see p. 556)
	Mooney Mooar, in <i>Glion Cam</i> , 200 and 250 yds. below high road	Two adits, one in each bank, respectively N. 30 E. and W. 35 S.
	S.W. of Granite Mtn., 300 yds. E. of head of <i>Struan Bar-rule</i>	Spoil heaps of slate ; ? small sinking
Sheet 13.	Corner of field 300 yds. S. of Ellerslie farm	Shaft
	Hillside 500 yds. S.S.E. of Ballingan	Adit
	West bank of Santon River, on S. side of road 350 yds. N. of Ballacorris	Small shaft

Sheet of 6 inch Ordnance Map.	Locality and Position.	Description of Working.
Sheet 13 (cont.).	East bank of stream at <i>Ballalough</i> , 200 yards S.E. of highroad bridge east of Richmond hill	Small excavation : trial ?
	Cliff at Fiddler's Green 700 yards S.W. of Douglas Head	Adit (see p. 544)
	Cliff at <i>Stack Indigo</i> , 600 yards S. W. of last	Adit, obliterated ; marked <i>Lead Mine</i> on 6 inch map
Sheet 14.	Cliff on E. side of Onchan Harbour	Short adit ; marked <i>Lead Mine</i> on 6 inch map
	Cliff on E. side of <i>Port Jack</i> , 600 yards S.W. of last	Adit, obliterated ; marked <i>Lead Mine</i> on 6 inch map
Sheet 15.	Cliff in <i>Ghaw Dhoo</i> on N. side of Bradda Hill	Adit.
	Cliff 150 yards W. of last	Adit ? near olivine-dolerite dyke (see p. 171)
	Hillside 300 yards W. of "West Bradda trial" (see p. 537).	Small trial
Sheet 16.	Head of Colby River 300 yards W.S.W. of Ballacannell	Adit in E. bank
	West bank of Silverburn, 150 yards S. of <i>Cregg Mill</i>	Adit (see p. 197)
Sheet 17.	Cliff at <i>Traie ny Gill</i> , 300 yds. W. of Port Greenaugh	Adit
Sheet 18.	Cliff in recess W. of Baroo Ned	Adit (see p. 532)
	Cliff at <i>Rheboeg</i> , Bay Stacka	Adits, marked <i>Mine</i> on 6 inch map
Sheet 19.	Cliff on E. side of Langness, N. of <i>Tarrastack Rock</i>	Two short adits, 40 yds. apart ; (for trials on W. side of Langness see p. 538.)

CHAPTER XIII.

NON-METALLIC PRODUCTS.

Umber and Ochre.	Roofing Slate.
Rottenstone.	Building Stone.
Fuller's Earth.	Road-material.
"Dun Earth" or "Asbestos."	Lime.
Vein-Quartz.	Bricks.
Coal Trials.	Sand and Gravel.
Salt.	
Peat.	

Umber and Ochre.

The production of these colouring earths in small quantity in the Isle of Man dates back at least from the beginning of the nineteenth century. Macculloch, in 1819, mentions that "yellow ochre has been found in sufficient quantity in some of the mineral veins, to have become at one time a matter of export," but that the mines had long since ceased to be wrought.¹ The mines referred to were probably Bradda and Ballacorkish, as Smyth notes the occurrence of the substance in these lodes.² In the documents relating to the transfer of the mineral rights of the Island to the Crown in 1827-8, Mallew is the only locality given for Yellow Ochre; at the same time a report of the Crown Agent states that "of this oaker there is great abundance in the Island of excellent quality" but that the lessee had failed to make it pay. From the somewhat incomplete returns given in "Mineral Statistics," as shown in the Tables at pp. 496-8, the production since 1858 seems usually to have ranged between 100 and 200 tons per annum.

The substance has been obtained from two distinct sources. One variety, prepared in the village of Ballasalla, is derived from the decomposed black flaggy Carboniferous Limestone (Castletown or Lower Limestone), which is often weathered at the surface and along irregular pipes and veins into brown earth, as may be seen in the cliffs north of Ronaldsway and in the large quarries west of Ballasalla. This change is especially noticeable where the limestone is dolomitised.³ During our survey of the district the principal supply was being obtained from shallow pits in the little outlier of Carboniferous rocks east of the fault near Athol Bridge, one mile N.N.W. of Ballasalla, at the place

¹ "Western Isles," vol. ii., p. 579.

² "List of Manx Minerals." Isle of Man Nat. Hist. and Antiq. Soc., vol. i., p. 145.

³ Similar decomposition of dolomitic limestone into umber in Devonshire has been described by R. J. Frecheville in a paper on "The UMBER Deposits at Ashburton." Trans. Geol. Soc. Cornwall, vol. x. (1884), p. 217.

marked U on the geological map. The 6-inch Ordnance (Sh. 16) shows an "*umber pit*" near the boundary of the lias at Billown, 600 yards west of the Ballahot quarries, but no longer worked and the section is obliterated. In preparing the substance, the raw material is pounded, washed and passed through settling tanks in which the umber remains as a fine paste, then dried and ground.

The other source of the material is from decomposed dolerite dykes and from rotten ferriferous slate and veins, and sometimes apparently from the ferruginous of the vein-stuff itself. Near the surface, both the dyke and the country-rock, as well as the vein, are occasionally jointed to a brown earth which furnishes the umber. The chief source of this variety has of late years been drawn from the dyke in the cliff on the southern side of Maughold Head, mentioned on p. 126, which follows the course of an olivine-dolerite that intersects the Drynane hematite-vein. This is known as the Baldroma Mine, and was last in operation between 1880 and 1893. In the upper part of the Silverburn basin, in a glacial drift about 100 yards S.W. of Garey Mooar, there is a similarly decomposed dolerite dyke, along which a short level has been driven, whether for umber or in search of other ores has not been ascertained.

Rotten-Stone.

At the umber works at Ballasalla a small quantity of 'rotten-stone,' for use as a polishing agent, has also been prepared, the raw material being a fine argillaceous silt, which has been isolated, apparently by rain-wash, in a boggy depression on the moorland between South Barrule and Cronk Fedjag. When used for the same purpose, this is, of course, an entirely different substance from the 'dun-earth' described below.

Fuller's Earth.

Information regarding the fine glacial clay which has been used for this purpose in Glen Wyllin near Kirk Michael will be found in Chap. XI., pp. 428 and 447.

'Dun Earth' or 'Asbestos.'

The 'Asbestos' (fibrous tourmaline) which occurs in the Dhoon Granite under conditions described in a previous chapter (p. 143) was mined for a time to a small extent for use as a polishing powder, early in the past century. The fact was mentioned by Woods, in 1811, as being in local use. Henslow, in 1821, described it as follows:—"Fibrous Asbestos occurs in a decomposing state near the Dun, in two veins about six inches broad, traversing the decomposed portion of the granite."

¹ "An Account, etc., of the Isle of Man," p. 17.

granite and gneiss. It is accompanied by quartz, which it penetrates and frequently colours. It may be taken from the vein in fibrous bundles of three or four inches in length, but it is in general so much decomposed as to have assumed an earthy form. . . . On pressing the fibres between the fingers they crumble to a harsh powder capable of taking away the polish from glass, and consequently very unfit to be used in cleaning plate, a purpose to which it has been applied. I found a single specimen in which the fibres were flexible. Specific gravity = 3.03."¹

A plan of the workings, dated 1826, is preserved at the Woods and Forests Office, showing three short levels, one on the northern and two on the southern side of the stream, with a note in reference to the northern level that "the mineral substance called Asbestos or polishing powder disappears at the end of the workings." A lease had been granted by the Duke of Athol for the mining of this substance, but the Crown Agent in reporting on it in 1827-8 remarks, "Mr. S—— wrought this for a short period and paid 15 guin^s of Lordship, but he abandoned the work some years ago, but whether from its being unprofitable or for other reason, I know not."²

Vein-Quartz.

The broad vein of this substance quarried on the N.E. side of the Foxdale Granite has been described on p. 166. It has been exported on a small scale; and is in favour locally for ornamental rock-work. A smaller quarry has been opened in a similar vein on the north slope of Kerrowgarroo, $\frac{1}{2}$ mile E. of Kennaa, near St. Johns (p. 164). The material occurs in strings and lenticular masses in every part of the Manx Slates, especially in the Barrule Slates (p. 320), but is generally more or less entangled with the country-rock and intermixed with small quantities of mica, chlorite, pyrites, etc.

Coal Trials.

The search for coal in the Island has been long and obstinate, and as yet fruitless. The earlier trials were foredoomed to failure, being for the most part ignorantly carried on in rocks older than the Coal-measures; while the later researches in the north, beneath the drift-covered plain, where alone some possibility of success existed, have, up to the present time, failed in their main object; though they have revealed a small salt-field which may prove of economic importance.

As previously noted (p. 481), we learn that, as far back as 1669, the ruling Lord of Man (Charles, 8th Earl of Derby) "being by good reasons persuaded that there is plenty of coales" in the

¹ Trans. Geol. Soc., vol. v., p. 498.

² MSS. Athol papers in Woods and Forests Office.

Island, ordered a search to be instituted; and Bishop Wilson, early in the 18th century, referred to several unsuccessful attempts having been made to find them.

Dr. Berger discussed the subject at some length in his memoir published in 1814, and gives reference to some older records in Curwen's "Agricultural Report" (Workington, 1810). He says:—"While I was in the Isle (June, 1811), two or three spots in the north-western part were particularly pointed out to me as places where coals did *actually* appear, or were *cropping out*. But when the matter was strictly enquired, the reports turned out unfounded. . . . The only serious attempt, I believe, to find coals in the Isle was made at Derbyhaven [in Carboniferous Limestone] many years ago by a speculator from Cumberland. After having gone to a certain depth, not finding traces of them, he gave up the search as fruitless."¹ Macculloch, in 1819, mentions, but discredits, the report that coal had been found in the red sandstone near Peel; and he adds that since his visit to the Island he had received fragments of coal said "to have been found under the limestone or in the conglomerate of Derbyhaven, where some expensive borings for that purpose were formerly made."²

It was no doubt the same supposed discovery which was referred to in the following terms in the "Manx Mercury" of 26th Nov., 1793³:—"We feel unspeakable pleasure in being able to announce to our readers that a stratum or bed of coal has been discovered near Derbyhaven in this Island, at a depth of about 60 feet from the surface of the earth." This statement was of course unfounded, but is still remembered and repeated in the locality.

From documents preserved in the Office of Woods and Forests it appears that the search was still fitfully continued during the first half of the present century. The resident Crown Agent, in reporting on the matter in 1836, says, "Many trials have been made and considerable sums expended, but always without success," and refers also to his "knowledge of many unsuccessful trials made by the late Duke [of Athol] to find coal." About this time a licence to search for coal was granted to E. Forbes, of Douglas (father of Professor Ed. Forbes)⁴ and others: and it is mentioned that trials had previously from time to time been permitted on the Waste Lands (of The Ayre?), but without result. In a "report of the Directors of the Isle of Man Coal Company," dated 22nd February, 1840 (quoted in the prospectus of a later company,) the following details of a boring at Ballasalla

¹ Trans. Geol. Soc., vol. ii., p. 56.

² "Western Isles," vol. ii., p. 574.

³ Quoted in the Prospectus of the "Isle of Man Coal Co., Ltd." (about the year 1870).

⁴ In an article on Manx Geology contributed by Prof. E. Forbes to Quiggin's "Guide to the Isle of Man," it is stated that in several places, both in the limestone and slate, specimens of anthracite or blind-coal occur, and that these had been mistaken for bituminous coal and led to useless researches (p. 56, 4th ed., 1852).

are given:—"The measures gone through at Ballasalla are, first, 7 yards white sandstone; secondly, 24 yards of layers of limestone, varied from 2 to 7 feet thick, with intermediate layers of soft blue clay; thirdly, 23 yards of old red sandstone in layers from 3 to 12 yards in thickness, with three layers of clay; fourthly, 5 yards ferruginous bands." It is stated that these explorations "abandoned for a time for the purpose of searching at the north of the Island, were intended to be resumed, but in consequence of the Company breaking and losing the boring rods, they declined to further prosecute the work." The top "sandstone" is probably drift, the lower beds being, of course, the Carboniferous Limestone and its Basement Conglomerate (see p. 196). The northern boring alluded to was probably that made at the Craig near St. Jude's Church in 1839, described by Cumming in a passage quoted on p. 280. A document in the Woods and Forests Office, dated 18th February, 1843, mentions that upwards of £1,000 had been spent in this search, which had been suspended two years previously.

Another company, with the title of "The Isle of Man Coal Company, Limited," the prospectus of which has been quoted above, was organised about thirty years ago to make further search for anthracite coal in the neighbourhood of Ballasalla and Derbyhaven, but no information is forthcoming as to its actual operations. In 1873 renewed explorations were also set afoot in the Peel district. All that could be learnt respecting these and the earlier trials in the same neighbourhood has already been stated (Chap. VI, pp. 278-9). The systematic and thorough investigation in the extreme north of the Island commenced by Messrs. Craine Bros. of Liverpool in 1891, and still in progress, has been fully discussed in a preceding chapter (Chap. VII., pp. 280-95).

Salt.

Steps are being taken to make economic use of the salt deposits discovered in Triassic Marls of the Point of Ayre borings, described on p. 289. It is proposed to pump the brine and convey it in pipes to Ramsey for treatment. In "Mineral Statistics" for 1895, p. 101, a return of 10 tons from this source is recorded—the first in the annals of the Island.

Peat.

Information regarding the distribution of peat and the places where it has been dug in the Island has been given in a foregoing chapter (pp. 415-6).

Roofing Slate.

Reference has previously been made (Chap. III., p. 50), to the many costly attempts to find roofing slate in the Island and to the uniform ill-success which has attended them. The unsuit-

able character of the cleavage and flow-structures (p. 73), as well as the prevalence of shear-planes and quartz-veins, and their combined detrimental effect upon the hardness and compactness of the slate-rocks sufficiently explain the failure of these attempts, and in most cases ought to have been a deterrent before the loss was incurred. These trials have been chiefly made in the Barrule Slates, but a few have taken place in slaty bands in the Niarbyl and Lonan Flags. In the aggregate probably not far short of £100,000 has been expended in this manner in the Island with scarcely any return.

Bishop Wilson in the middle of the 18th century referred to blue thin light slate as a matter of export¹; and Berger, in 1814, mentioned roofing slate as being obtained at Peel Hill and Ballagawne.² The oldest of the systematic trials is probably that at the northern end of the ridge of South Barrule, which is included in the schedule of the property transferred from the Duke of Athol to the Crown in 1827-8. At that time the slate-quarries of the Island were under lease to Mr. Knott; but from the report of the Crown Agent it appears that the tenant had met with opposition from the natives "who at their own hand and without the authority or licence of the lord had been accustomed to work the same."³ This custom is referred to by Cumming, who states:—"By the insular laws every person standing in need of limestone or building stone may enter on his neighbour's land and dig and carry away what is requisite for his own use, paying the occupier a reasonable satisfaction which appears to be interpreted merely surface damage."⁴

Between 1860 and 1870 a very large amount of development work was done upon the South Barrule quarry; and about the same period more or less extensive openings were made, among other places, at the north side of Maughold Head near Port e Myllin (p. 124); at the head of Ballure Glen, south of Ramsey (p. 136); at several spots in Glen Auldyn; in Sulby Glen near the mouth of the Block Eary tributary (p. 133); in Glion Kiark on the northern slope of Sartfell (p. 138); in the valley of the Neb near the mouth of Glen Helen and lower down opposite Ballig (p. 157); on the coastward side of the hill south of Peel (p. 147); on the northern slope of Slieau Whuallian near Glenaspit; on the western side of Foxdale near Ballageay (p. 162); in the West Baldwin valley west of Awhallan (p. 157); on the western side of Greeba Mountain; on the east coast, at Bulgham Bay and a few other places; in Glen Rushen above Glen Meay (p. 163); and on Cronk Fedjag (p. 164). Numerous other localities where work was done on a smaller scale are mentioned among the topographical details in Chap. IV. The workings were mostly open quarries, but in a few cases shafts were sunk and galleries driven. Some produced a small quantity of slates, of inferior

¹ "History of the Isle of Man" (Cruttwell's ed. of 1786), p. 343.

² Trans. Geol. Soc., vol. ii., p. 38.

³ MSS. in Woods and Forests Office.

⁴ "Isle of Man," p. 311.

quality and in no instance good enough to compete with Welsh slates ; the best seem to have been obtained from a narrow slaty band in the Niarbyl Flags south of Peel (see p. 147). For many years all these trials were abandoned, but work was resumed recently for a short time at the South Barrule quarry.

Sir W. W. Smyth's official reports contain many references to these quarries during the years of their activity, and as some of the workings are now filled with water or otherwise inaccessible, a few notes from this source may prove useful. In 1862, after describing several of the quarries, he remarks that he had seen no slate as yet opened in the Island good enough for exportation. In 1863, he notes that 120 men were at work in Glen Rushen on rock of a lamentably poor character ; that South Barrule had some rather better slate ; and that at Baldwin, where twenty men were employed, there was no rock at all like slate. In 1864, at South Barrule, with forty-five men, a fair quantity of material had been raised, and met with a ready local sale but was not good enough for an export trade. In 1865, the most effective trial was being made at Ballamoar [near St. Johns] by sinking a shaft ; and in the following year it is noted that at this place a tunnel had been driven a long way into the hill, finding throughout the same even-splitting slate, too soft to be applicable ; in the same year, workings at Peel, Sartfell, Sulby Glen, Glen Auldyn and Maughold are also mentioned. In 1867, Smyth remarks that speculation had greatly cooled ; that at Maughold some slate had been got, but with too much waste ; at Glen Auldyn the lower gallery might do for local consumption ; and at South Barrule it was too clear that the middle part of the quarry was too bad to touch, and the north and south ends, which were better, must be worked into the mountain independently, and some good piles of second-class slate had been got from the north end. In the following year we read :—"I regret to record the almost total collapse of this branch of industry, buoyed up as it has been chiefly by ignorant hopes on one side and false representations on the other." Two or three quarries however were still carried on, including that of Rhenass (Neb valley), the rock of which is described in subsequent reports as coarse and full of quartz, fit only for rough local purposes ; and that in the Sulby valley, regarding which it is noted in 1871 that better stone had been found in a cut 8 yards below the chief floor, "but there is much spar all through the quarry still, and the cleavage is so imperfect that the product would certainly not be saleable in England or Wales" ; 95 men were employed in this quarry in 1873, but it seems to have been abandoned two years later. The report for 1876 describes a spirited trial near Peel, where twenty men had been at work on a vein, only 32 feet wide, narrowing inshore and with a high cliff above, which rendered difficult any system of economic extraction ; "several cargoes amounting to perhaps 100,000 slates have been sent away," but the enterprise was to be abandoned. In 1877, two or three men were at work at South Barrule only, and in 1880 no work was being done, "not even on South Barrule."

Building Stone.

Quarry-stone is the common building-material in the Island, and is usually obtained from whatever source is nearest, whether Manx Slate Series, Peel Sandstone, or Carboniferous Limestone, while in the drift-plain of the north glacial boulders are largely used.¹

¹ For special purposes, and for the more elaborate buildings, stone is occasionally imported from the mainland : Wood's notes (op. cit., p. 22) that the old Douglas Pier was built of stone from Runcorn, and Mona Castle of sandstone from Arran.

Manx Slate Series.

From the large area which they occupy, the Manx Slates furnish by far the greater proportion of the ordinary building stone, but the quality is inferior. It was adequately described long ago by Bishop Wilson as a "broken ragstone sometimes rising in coarse uneven flags, or in irregular lumps," which "an English mason would not know how to handle, or would call their walls, as one merrily did, 'a causey reared up upon an edge.'"¹ The material cannot be dressed, except very roughly, and is quarried in irregular slabs along whatever happens to be the dominant fracture-plane,—usually the bedding where the rock is somewhat arenaceous, and the shear-cleavage planes where it is argillaceous. The stone is best where the two structures are approximately parallel, but even then there is usually a cross-cleavage or close-jointing oblique to the dominant structure, which causes irregular acutely-angled edges to the blocks. All varieties of the slate-series are used, even including the crush-conglomerate (near Ramsey, p. 66), but the best stone is obtained from the Lonan and Niarbyl Flags and from some of the laminated passage-beds, while the quartz-veined grits are least in favour and are generally set aside for road-metal. In the north-western corner of the massif, north of Glen Wyllin and west of Glen Dhoo, and in a few other more limited tracts, the rock breaks up into faggot-like pieces along the intersecting structural planes (p. 131) and is of little use. In most buildings of rough slate, brick or dressed stone is employed at the angles and around doorways, windows, etc. On St. Michael's Island, Langness, the well-preserved walls of a fort built in 1650 contain many blocks of a schistose greenstone dyke which crops out in the vicinity (p. 181); and this stone, in spite of the exposed situation, has withstood the weather remarkably well—even better than the accompanying slate, which is itself very enduring.

A variety of the slate-rock which was formerly quarried, as described at p. 174, both on the crest and at the foot of Spanish Head was especially valued for its quality of raising in very tough and strong beams, somewhat flexible, and up to 15 or 16 feet in length, which were used for lintels, gate-posts, foot-bridges (p. 132), etc., and in Castle Rushen for flooring (p. 174). As previously mentioned, Macculloch states that a beam of this material 15 feet long and 2 inches thick was forced 5 inches out of the straight line before it broke. The top quarry seems to have been in working as late as 1858 (see "Mineral Statistics" for 1858, pt. ii., p. 269). The slate is of the banded argillaceous type, and its peculiar quality seems to have arisen from the compression of the rock in the trough of a fold, with the resultant intersection of flattish bedding by steeply inclined shear-cleavage. Under similar circumstances, in a quarry on the steep slope between Ballaugh and Gob y Volley, beams of the same kind of

¹ Bishop T. Wilson's "Description of the Isle of Man" (Camden: Britannia ed., 1772), p. 392.

stone up to 24 feet in length have been raised, as described on p. 132; and probably these conditions might be likewise found in other places more accessible than Spanish Head. Though not at present worked, the material seems well fitted for various economic uses if it could be got at a reasonable cost.¹

The building-stone quarries in the Slate Series are usually small, being opened as occasion requires, near the place where the material is needed. At Douglas, however, there are large quarries (in the Lonan Flags) on the southern side of the harbour and near the northern extremity of the Bay (p. 153); and openings in the hill-side south of Ramsey have also attained a considerable size. From the quarries working under the Quarries Act and giving returns to the Home Office, the output for 1897 (Mineral Statistics, p. 140) is stated to have been 17,560 tons of the value of £1,056; in 1898 (*ibid.*, p. 248), 21,508 tons, value £1,282; in 1899 (*ibid.*, p. 256), 19,005 tons, value £1,057; and in 1900, 13,524 tons, value £754.

Peel Sandstone.

This red sandstone, being the only 'freestone' available in the Island, has been extensively quarried at Creg Malin and Ballaquane, north of Peel. The characters of the formation have been fully described in Chapter VI., p. 263. Only a small part furnishes building stone, the thin and irregular bedding and the shaly and conglomeratic intercalations being detrimental in the greater portion. The stone is only moderately durable, as may be seen from the condition of part of the ruins at Peel Castle on St. Patrick's Island. The output for 1897 ("Mineral Statistics," p. 140) is given as 2,800 tons of the value of £166; for 1898, 1,240 tons, value £76; for 1899, 1,827 tons, value £112; and for 1900, 1,218 tons, value £101.

Carboniferous Limestone.

Besides affording the chief source of lime for the whole Island and being to some extent used for road-mending, the dark grey flaggy Lower or Castletown Limestone of the southern basin supplies the local building stone, both dressed and in the rough. For the last-mentioned purpose, when carefully selected it is structurally well adapted, though somewhat dingy in colour; the excellent state of preservation of Castle Rushen at Castletown bears testimony to the durable quality of this stone. The principal quarries at present working are those at Ballahot and Billown, three-quarters of a mile W. of Ballasalla (p. 206), and that near Scarlet on the W. side of Castletown Bay (p. 203). The output given in "Mineral Statistics" for 1898 (p. 230) is

¹ Berger (op. cit., p. 37) and Macculloch (op. cit., p. 532) also mention among the economic products of the Island a "hone slate" occurring "at a place called Montpellier." The latter author describes the stone as "of a whitish colour and soft texture better adapted for the polishing of metallic plates than the uses of the cutler. It has not been exported." This stone is no longer in use, and I have failed to identify the locality referred to.

12,372 tons, value £2,813; for 1899 (*ibid.*, p. 238), 9,272 tons, value £881; and for 1900, 9,315 tons, value £895.

The so-called 'black marble' of Poolvash was obtained from the harder courses in the black flaggy and shaly "Posidonomya Beds" on the eastern shore of Poyll Vaaish, as described on p. 224, but is not at present worked. The best stone seems to have been found immediately underlying the volcanic ash, where the rock has been indurated, probably by a slight over-thrust of the Volcanic Series (p. 224). Among other uses, it was wrought into chimney-pieces, tombstones and steps. Being too soft to take a natural polish, it was covered with a kind of black varnish, and in this way objects wrought out of it were "made to look not much inferior to the best Derbyshire black marble."¹ The tombstones made from it show rapid weathering. The "steps of St. Paul's Cathedral in London," so often mentioned in Manx topographical literature as having been supplied from this locality, seem to be no longer in existence (p. 220). The total extent of the 'black marble' quarrying has not been great.

Granite.

In the district S. and S.W. of the Foxdale Granite, where glacially transported boulders of this rock are numerous, they have been largely used in building, but have shown themselves subject to very unequal weathering. A quarry was opened some years ago on the northern slope of the granite outcrop, but was not worked to any great extent; the operations have however been recently resumed. The rock is massive and not too hard, but is somewhat liable to crumble after exposure. The granite was formerly raised in long beams and shaped into rollers for agricultural purposes, and it is worth mentioning that fragments of these broken rollers may readily be mistaken for boulders in parts of the island when there are no true boulders of this rock.

The Dhoon Granite, being much harder and closer in texture, has been quarried for road-mending and for making paving setts; the latter industry was revived recently on an extensive scale for a short time, but has now again flagged. The following note respecting the quality of the granite is quoted from the Journal of the Isle of Man Nat. Hist. and Antiq. Soc. for 1898 (Yn Lioar Manninagh, vol. iii., pt. x., p. 488). "The granite of the Dhoon has been tested for road setts and other purposes. The results under compression, such as percussion and attrition tests, show that it is a most excellent stone for all road purposes, and most durable as a building stone. If basalt average 6 or 7·2, Dhoon is 7·3: Aberdeen granite . . . showing . . much . . below Dhoon."

The Oatland Granite is at present used only for road material, for which purpose it is extensively quarried.

¹ Cumming, "Isle of Man," p. 132.

Boulders.

In the northern drift-plain the absence of solid rock has led to the extensive use of glacial boulders both for road-mending and building. For the latter purpose the chief rock is the abundant Criffel Granite, the larger blocks of which are blasted into pieces and trimmed into shape; a good example of its use may be seen in Bride Church. Besides those found inland, large numbers of boulders are obtained from the shore, where they accumulate from the waste of the cliffs. Some have done duty over and over again in successive buildings, and the walls of old cottages in this tract are often interesting to the glacialist from the medley which they exhibit; but there is a striking rarity of limestone, this rock having been set aside for burning into lime.

In parts of the Island where the drift contains only local blocks these are sometimes also put to economic use.

Road Material.

Though subject to a brisk stream of carriage and waggonette traffic in the summer-time, the Manx high-roads are not often called on to bear heavy crushing loads, the vehicles used in agriculture being chiefly one- or two-horse carts and not heavy waggons. Consequently good results are obtained from stone of a quality unsuitable for more ponderous traffic, and a supply is usually got without much difficulty from a local source. Among the rocks thus laid under contribution are the quartz-veined grits and other hard beds of the Manx Slate Series, the Carboniferous Limestone, the Dhoo Granite and the Oatland Granitite. But the toughest and best material is furnished by some of the dykes, especially those of the 'newer greenstone' type (p. 297), intrusive into the Manx Slates: the only drawback being that these are usually narrow and discontinuous, and sometimes spoilt by shearing. These dykes, locally known as 'pot-metal,' have been quarried on a small scale here and there all over the slate area (for details see Chap. IV.); and at Poortown, 1½ miles east of Peel, a coarsely porphyritic boss of diabase is extensively worked (see p. 156). As a general rule the dykes lettered D and B^p on the map are, where thick enough, suitable for road-metal unless deeply decomposed; while those lettered B^a are usually too much altered by shearing to afford durable material.

At Crosby a broad dyke of microgranite of the Foxdale type furnishes much road-material of fair quality (p. 168). Accessible exposures of this kind of dyke-rock also occur in the West Baldwin valley (p. 158); at the side of the road between Foxdale and Castletown (p. 167); and at other places shown on the map; but have not yet been tested. These elvans, like the older 'greenstones,' are, however, sometimes spoilt by the platy structure developed by earth-movement.

The dykes associated with the Dhoo Granite (pp. 144-6) have not been quarried in the interior, as their chief outcrops are rather

inaccessible, but would probably supply material as good or better than the Foxdale elvans. The use of the granite itself for paving setts has already been mentioned.

Another dyke-rock which though not hitherto tested would probably yield tough and durable stone, is the mica-diorite of Port Groudle (p. 152); this could be conveniently excavated at its outcrop on the north side of Banks Howe; it occurs in a district where there is a comparative dearth of suitable stone.

The olivine-dolerites even where not too small are usually too much decomposed to be serviceable.

Boulders and gravel from the beach are made use of in many places near the coast, especially in the north of the Island where drift-material of this kind affords the only local supply.

Lime.

At present lime is prepared only in the Carboniferous Limestone tract of the south of the Island; but it was formerly burnt locally from a cornstone band in the Peel Sandstone near The Stack (p. 275); and at many places, especially in the north, from glacially-transported limestone boulders collected on the shore, the ruins of old kilns which one finds in unlikely places having generally been thus supplied. Berger, who quotes statistics showing that 84,992 barrels of lime had been sold from kilns in the south-eastern part of the island between the years 1807 and 1811, mentions that the northern farmers preferred the lime from the boulders to that from the southern limestone for manuring the land. The Manx Slates are essentially non-calcareous, the only portion possessing more than a mere trace of lime being certain fine-grained bands in the Niarbyl Flags, which contain up to 4·4 per cent. (p. 36), and a few sparingly calcareous nodules in the Lonan Flags (p. 34). The ruins of the ancient chapel on St. Michael's Island, Langness, show a very enduring mortar prepared from burnt sea-shells.

Brickearth.

At the time of the Survey, brick-making was being carried on only at three places in the Island—one in the N., on a very limited scale, at Regaby Beg (section described on p. 437); one in the W., in the valley of the Neb at Peel (described on p. 457); and one in the E., at Highton, one mile W. of Douglas (p. 455). The material in the first is weathered red boulder-clay; in the second, decomposed slate; and in the third, mixed slaty drift.

Disused brick-yards were noticed at West Craig, near St. Jude's (p. 437); at Ballacoarey, 1½ miles E.S.E. of Andreas; near Ballakelly, 1 mile W.N.W. of Andreas; at the northern end of the Mooragh at Ramsey; and at Port Lewaigue, 1 mile S. of Ramsey (p. 443), all in red boulder-clay: at Ballawyllin, a mile W. of St. Johns, in similar material (p. 458); and in the valley of the Neb,

nearly a mile north of St. Johns, in slaty till (p. 453). Except near the surface, where it has been thoroughly leached the red boulder-clay appears to contain too much lime to make good bricks. The decomposed slate used at Peel furnishes a dense hard brick of a dullish colour. The operations in the Neb valley N. of St. Johns proved a costly failure, but whether from the nature of the material or from want of care in burning is not apparent.

In "Mineral Statistics" the Manx output of clay for brick for 1895 is given as 6,793 tons, value £339; for 1896 6,000 tons, £275; for 1897, 8,914 tons, £360; for 1898, 10,100 tons, £460; for 1899, 7,000 tons, £175; and for 1900, 8,000 tons, £500.

Sand and Gravel.

These materials are obtained from the glacial deposits of the extra-insular type (p. 335) on the flanks of the Island, where they are abundant, but are not found of serviceable quality where the drifts are entirely of the local type.

CHAPTER XIV.

AGRICULTURAL GEOLOGY AND WATER SUPPLY.

Soils, etc.

The glacial deposits are the chief factors in determining the character of the soil in the cultivated portions of the Island, as the principal tracts of solid rock occur on the mountains above the limits of cultivation. The northern plain, which constitutes the largest area of fertile land, exhibits the variability commonly found wherever drift has accumulated thickly, ranging from stiff clay to light sand and gravel, with peaty patches in the hollows. In this case, however, the boulder-clay rarely forms the stiffest soil, having a sufficient admixture of sand to work into loam at the surface; and the beds of laminated clay belonging to the stratified part of the drift make the heavier land. The difficulty of indicating the kind of soil under these conditions by the conventional methods of drift-mapping has been discussed in Chapter XI. (p. 430), where information will be found as to the localities where the map might seem misleading. The practice of 'marling' the lighter tracts was at one time universal in this area, but is now practically abandoned except on the blown-sands along the southern edge of The Ayre. As already described, the 'marl' usually consisted of boulder-clay or stratified glacial clay (p. 418), but occasionally of late-glacial or post-glacial fresh-water deposits (pp. 378-81); both contain some lime (pp. 464-5), but, as Cumming remarked, the benefit to the land was probably more on account of improved texture and general renovation than from this ingredient alone.¹ Berger mentions that "150 tons of marl are computed to be necessary for an acre of land," but this was probably an extreme quantity; he adds that the cost of the operation was £6 per acre if the cartage did not exceed a mile, and that "the cost of liming, a practice chiefly used in the southern part of the isle, is nearly the same," 90 bushels of lime to the acre being allowed.² Seaweed is still extensively used for manure in parts adjacent to the coast, and in this way, as well as by 'marling,' many pebbles etc. have been artificially introduced into the soil,—a fact to be borne in mind by the glacial geologist.

Next in importance to the northern plain as an agricultural tract is the southern lowland, overlying the Carboniferous rocks

¹ "Isle of Man," p. 306.

² Trans. Geol. Soc., vol. ii., p. 55.

and extending beyond them up the gentle slopes of slate to 600 feet or more above sea-level. The lower ground in this tract closely resembles that of the northern plain, excepting that sand-and-gravel soils are less prevalent and tend to be more loamy, and the boulder-clay soils are darker, tougher and more calcareous. On the upland slopes the drift is mainly derived from the local slates and, though mapped as 'boulder-clay,' gives rise to soil which is not, as a rule, stiff, but usually a deep stony loam full of subangular fragments of slate, with patches of thinner rubbly soil where bosses of the solid rock approach the surface. This kind of land is predominant all over the hilly tracts wherever agriculture is attempted. Where the soil consists entirely of loose slaty débris, derived either from the subjacent decomposed rock-surface or from slaty drift of the gravelly type, it is termed by the Manx farmers "shilly" land; this produces better crops than its extremely stony appearance would lead one to expect, especially of oats, turnips, and potatoes; but it loses moisture rapidly, and suffers in a dry season. The patches of cold wet clay-land, difficult to drain and difficult to cultivate, occurring on flats and depressions both on the uplands and at the foot of the hills,—the result of the rain-wash and weathering of the drift—have been described in a previous chapter (p. 453); such 'Colby wash' soil has usually a dark grey colour instead of the rusty brown of the mellowed slaty land, and is generally full of bits of vein-quartz which have remained unaltered while the slate fragments have decomposed into mud.

On the eastern flank of the Island there is more or less cultivation on the hill-slopes from end to end, but on the western side the cultivated strip extends only as far south as Dalby. In the interior, south of the central valley the greater part of the drift-covered area is or has been tilled, but among the hills north of that valley a much smaller proportion is cultivated, and the area devoted to upland sheep-walks is constantly increasing at the expense of tillage. Macculloch as long ago as 1819 pointed out that the cultivation of elevated ground had in some places extended "further than prudence would have dictated or profit will ultimately justify";¹ and his dictum has been fully borne out, the uplands being everywhere dotted with the ruins of deserted cottages and small farmsteads; the little fields surrounding them, once under the plough, now producing only rough pasturage. This diminution in the proportion of arable land, as marked in the Island as in Great Britain and Ireland, is illustrated in the following statistics.² These figures also show to what an insignificant percentage the growth of wheat has shrunk, the grain

¹ "Western Isles," vol. ii., p. 519.

² From the annual Parliamentary Blue books: "Agricultural Returns." In the Return for 1899, the quantity of "Mountain and Heath land used for grazing" (not included in the Table) is given as 23,110 acres, and "Woods and Plantations" as 826 acres.

crops now consisting almost entirely of oats and barley, turnips and potatoes as the principal root crops.¹

Year.	Total area of Land and Water.	Wheat.	Barley.	Oats.	Green Crops.	Clover and Grasses under rotation.
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
1866	145,825	8,075	7,738	11,010	12,208	25,309
1876	"	6,181	7,210	12,324	12,045	34,373
1886	"	1,128	9,256	13,485	11,859	42,026
1893	145,011	800	7,452	13,789	11,263	38,009
1899	"	1,018	7,258	13,268	10,983	38,670

Water Supply.

The water supply of the Island is practically all obtained from the surface-streams or from shallow wells, there being no available deep source. The slate-rocks are waterless, except slight percolation along the lodes (see description of mine 532-3, etc.) and along joints near the surface in the quartz-grits; consequently there are scarcely any true rock-springs, though water oozes out abundantly from the base of the local drift and shaken rock on the hill-slopes and valleys. The Carboniferous Limestone of the south is too bedded and intercalated with shale to afford a good supply; few wells have been sunk in it (pp. 207, 471); some deep ones in this rock W. of Ballasalla are unwatered by wind-mill power, the discharge being of good quality, and estimated to average about twenty-six million gallons per annum².

All the towns possess organised water-systems supplied by reservoirs near the heads of the streams, Douglas thus utilises the Glass and the Groudle Rivers; Castletown, the Silverburn; Mary and Port Erin, the Colby River and a stream E. of Port Erin; Peel, a stream from the Slieve Whallian ridge and

¹ Berger quotes (op. cit., p. 32) the following figures from J. C. (1810):—

"Acres.
 100,400 of mountain.
 69,045 for grazing.
 30,158 in oats.
 15,079 under barley.
 14,761 under green crops, 710 of which may be considered as potatoes.
 9,047 in wheat.
 7,270 in roads, rivers, houses.

Total 245,760 acres."

But as this total greatly exceeds the actual acreage of the Island, it is not of much use for comparison.

² We are indebted to T. Moore, Esq., for this information.

at Rushen; and Ramsey, the head of Ballure Glen. The latter districts depend either upon the streams or upon small low wells, often very inadequately protected from contamination; the latter, on the low ground, are generally in water-logged drift not far below the surface; and in the hilly districts usually little basins excavated in the slate in a position to intercept the percolation between the solid rock and the overlying drift. The conditions of supply on The Ayre and other parts of the northern plain have previously been discussed (pp. 285 & 417), and particulars of a few wells in other districts given in Chap. XI.

APPENDIX I.

LIST OF MINERALS KNOWN TO OCCUR IN THE ISLE OF MAN.

(The Lode-Minerals are mainly on the authority of Sir W. W. Smyth's List, in Trans. Isle of Man Nat. Hist. and Antiq. Soc., vol. i., pp. 143-147.)

Name.	Localities and Remarks.	
	Lode-minerals.	Rock-forming minerals.
Actinolite	—	As alteration-product in dyke-rocks (p. 308).
Albite	—	In some igneous rocks.
Analcime	—	As decomposition-product in basalts.
Anglesite	Glenschass Mine (s) ¹ - -	—
Anthracite	Laxey Mine (see p. 520)- -	—
Antimonite	Niarbyl Mine, (p. 546) - -	—
Apatite	In a vein near Foxdale Granite (Kendall)	In small crystals in many igneous rocks.
Atacamite	North Bradda, old workings (s)	—
Augite	—	Common in intrusive rocks.
Barytes	Foxdale; rare at Laxey (s); North Laxey	—
Biotite	—	Common in igneous rocks, and detrital in slates.
Calamine	Laxey (rare) (s) - - -	—
Calcite	Common in lodes - - -	Chief constituent of limestones, and alteration-product in basic igneous rocks, etc.
Cerussite	Glenschass, Rushen, and Bradda Mines (s).	—
Chalcanthite	Old workings, Laxey, Bradda (s)	—
Chalcedony	Cornelly Mine: as <i>Agate</i> in Bulwark Lode, North Bradda (s)	As pebbles, in Peel Sandstone and in Glacial deposits.
Chalco-pyrites	Laxey: Foxdale (rare); Maughold Head; Langness (s), and other places	—
Chalybite (Siderite)	Foxdale, Cornelly, and other mines	As decomposition-product in some igneous rocks.
Chlorite	Bradda and Rushen Mines (s), and common in quartz veins	Common as alteration-product.
Chloritoid (Ottrelite)	—	In altered elvan on Greeba Mountain (p. 318) and probably in other altered rocks.
Cuprite	Bradda Mine (s) - - -	—
Diagite	Snaefell Mine (s) - - -	—
Dolomite	Common in lodes - - -	In Carboniferous Limestone and sparingly in decomposed basic rocks.

¹ Localities marked (s) are from Sir W. W. Smyth's list.

	Localities and Remarks.	
name.	Lode-minerals.	Rock-forming minerals.
quartzite	—	Common as alteration-product especially in basic dykes.
epidote Tetra- drite)	—	—
garnet (see diopside, pyroxene,	Old Foxdale (s) - - -	—
calc-spar	In many lodes : more or less argentiferous	—
fluorite	—	As alteration product ; and detrital in grits.
graphite ?	see p. 549 - - -	—
white mica	Snaefell Lode (impure) (s). Beary (p. 550).	Graphitic slate in several localities : see p. 134.
chlorite	Many veins in Triassic and Carboniferous rocks in deep borings on The Ayre.	—
biotite	Maughold Mines - - -	—
hornblende	Cornelly lode (s) - - -	Common in intrusive rocks (see p. 301).
pyroxene	—	Common in many rocks.
pyrites	Common in lodes - - -	Common in many rocks.
ferrous nickel	Glenchass (s) - - -	—
chromite	—	In basic igneous rocks.
monazite	—	As decomposition-product in igneous and metamorphic rocks.
zirconite	Maughold Mines (s) - - -	—
apatite	—	Common in igneous rocks.
white mica	Bradda Lode (s) - - -	—
actinolite	—	Variety of augite common in basic dykes (p. 301).
garnet-sear (see albite)	Laxey, Bradda (s), etc. - - -	—
basaltic ironstone	Laxey and Bradda Mines (s) - - -	—
hematite (see magnetite, etc.)	Old workings, Laxey, etc. (s) - - -	—
malachite	—	In Dhoon Granite elvans and in granite at Cornelly Mine.
pyrite	Trial-shaft at Rhenas (s) - - -	—
pyrrhotite	On joints in Dhoon Granite - - -	—
covellite	In many quartz veins (p. 320)	Common rock-constituent.
silica ores see Kupf- nickel and Mill- ite)	Rushen and Bradda (s) - - -	—

Name.	Localities and Remarks.	
	Lode-minerals.	Rock-forming min.
Oligoclase	—	Common in some igne
Olivine	—	In basaltic dykes.
Opal	Var. semi-opal; Cornelly Mine (s)	—
Orthoclase	—	Common in igneous r
Picotite	—	In Carboniferous
Plumbago (see Gra- phite)	—	(Hobson).
Plumosite	Foxdale Mine (p. 503) - -	—
Pyrates (see Iron - pyr- ites and Chalcopyr- ites)	—	—
Pyrolusite	Upper part of several lead- veins (s)	—
Pyromor- phite	Rushen and Laxey Mines (s) -	—
Pyrrhotite (Pyrrhotine)	Snaefell; Laxey (rare) (s) -	—
Quartz	Chief constituent of veins in slates	Common rock-constit
Riebeckite	—	In Ailsa-Craig bouldr drift.
Rutile	—	Common in altered sl in some igneous roc
Sericite	—	Common as alteration in sheared rocks.
Serpentine	-	As decomposition after Olivine.
Silver-ore (see Fah- lerz and Plumosite)	—	—
Sphene	—	As alteration - produ neous and metamorp
Staurolite	—	As alteration-product gin of Dhoon gran (G. Barrow.)
Steatite	Foxdale and Laxey Mines (s)	—
Stibnite (see Antimonite)	—	—
Tetrahedrite	Foxdale Mines (s) - - -	—
Tourmaline	In quartz-veins near granite (see p. 143).	Common as alteration in igneous and met rocks, etc.
Tremolite	—	Alteration-product dykes.
Uralite	—	Variety of hornblende in basic dykes (see
Zinc-blende (Sphalerite)	In many lodes - -	—
Zircon	—	Small grains in grits igneous rocks.
Zoisite	—	As alteration-product neous rocks.

APPENDIX II.

SOME PUBLISHED ANALYSES OF MANX ROCKS.

Analyses from Dickson and Holland's paper:—on "An Examination of some Volcanic Rocks of the Isle of Man," in Proc. Liverpool Geol. Soc., vol. vi. (1889), pp. 126-129.

Specimen showing junction of microgranite dyke at Crosby with the slates.

"Analysis of Elvanite portion of specimen."

"Sp. Grav. 2·72.¹

SiO ₂	-	-	-	-	-	-	74·39
Al ₂ O ₃	-	-	-	-	-	-	15·55
Fe ₂ O ₃	-	-	-	-	-	-	1·35
MnO	-	-	-	-	-	-	0·22
CaO	-	-	-	-	-	-	0·48
MgO	-	-	-	-	-	-	0·33
K ₂ O	-	-	-	-	-	-	2·14
Na ₂ O	-	-	-	-	-	-	3·79
Combined water	-	-	-	-	-	-	1·18
							99·43

"Analysis of the slaty portion of the rock at the point of junction.

SiO ₂	-	-	-	-	-	-	49·03
Al ₂ O ₃	-	-	-	-	-	-	24·83
Fe ₂ O ₃	-	-	-	-	-	-	3·68
FeO	-	-	-	-	-	-	5·57
MnO	-	-	-	-	-	-	0·26
TiO ₂	-	-	-	-	-	-	1·09
CaO	-	-	-	-	-	-	1·80
MgO	-	-	-	-	-	-	2·68
K ₂ O	-	-	-	-	-	-	5·09
Na ₂ O	-	-	-	-	-	-	2·96
Combined water	-	-	-	-	-	-	2·57
							99·56

"Not enough of the specimen remained to enable a satisfactory estimation of the carbonaceous matter to be made. P₂O₅ was detected in this specimen, but was not estimated, as also S.

"Thinking it would be interesting to have a specimen of the unaltered slate rock examined chemically so as to compare it with the rock near the point of junction, a specimen was kindly sent by Dr. Tellet of Ramsey from Sulby, a place about 5 miles from Crosby."

¹ Mr. Hobson states that the sp. grav. of this rock is 2·62 (Quart. Journ. Geol. Soc., vol. xlvii., p. 439).

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Carboniferous shale from a deep boring [Knock-e-Dooney] in the Isle of Man," by W. Maynard Hutchings (in "Clays, Shales and Slates"; Geol. July, 1896, dec. iv., vol. iii., p. 309).¹

Silica	-	-	-	-	-	-	58.75
Alumina	-	-	-	-	-	-	19.15
Ferric Oxide	-	-	-	-	-	-	3.90
Lime	-	-	-	-	-	-	1.15
Magnesia	-	-	-	-	-	-	1.95
Potash	-	-	-	-	-	-	3.48
Soda	-	-	-	-	-	-	1.54
Carbon dioxide	-	-	-	-	-	-	1.26
Water and organic matter	-	-	-	-	-	-	8.87

100.15

¹ specimen analysed by Mr. Hutchings was from a depth of 805 feet above boring; see page 582.

APPENDIX III.

DETAILS OF DEEP BORINGS.

No. 1 BORING: POINT OF AYRE. (See p. 289.)

Details published by Prof. W. Boyd Dawkins in *Trans. Ma Soc.*, vol. xxii, p. 600, and by J. Todd in *Yn Lloer Manninag* p. 71.)

Formation.	Engineer's record.	Thickness
		Ft. in.
[Raised Beach]	Shingle - - - - -	23 0
	Sand and shingle - - - - -	70 0
	Running sand - - - - -	6 0
	Clay - - - - -	3 0
	Sand and gravel - - - - -	2 0
	Clay - - - - -	6 0
	Hard sand - - - - -	9 0
	Clay - - - - -	8 0
	Hard sandy clay - - - - -	20 0
	Clay - - - - -	3 0
	Sand - - - - -	4 0
	Clay - - - - -	4 0
	Sand - - - - -	8 0
	Soft sandy clay - - - - -	2 0
	Hard brown clay - - - - -	10 0
	Gravel - - - - -	2 0
	Sandy boulder clay - - - - -	4 0
[Glacial]	Sand - - - - -	3 0
	Sand with stones - - - - -	6 0
	Hard sand - - - - -	6 0
	Silt - - - - -	17 0
	Sand - - - - -	2 0
	Hard sand - - - - -	10 0
	Sand - - - - -	69 0
	Gravel - - - - -	1 0
	Mottled brown and grey marl - -	54 0
	do. do. with gypsum - -	101 0
	Light blue marlstone - - - -	3 2
	Brown and blue marl - - - -	44 9
	Light blue marlstone with salt -	11 0
	Brown and grey marls with salt -	19 9
	Brown marl with veins of gypsum -	1 6
	Light blue marlstone - - - -	3 9
	Brown marl with veins of gypsum -	1 0
[Triassic : Saliferous Marls]	Brown marl and blue marlstone -	26 11
	Marl with salt - - - - -	0 10
	Blue marlstone - - - - -	1 6
	Brown marl - - - - -	3 2

¹ Descriptions, throughout, in square brackets are not cor the original records.

Formation.	Engineer's record.	Thickness.	Depth.
		Ft. in.	Ft. in.
[Triassic : Saliferous Marls]	Brown marl, with blue marlstone containing veins of gypsum and salt	45 1	615 5
	Brine run - - - - -	2 6	
	Blue marlstone - - - - -	8 1	
	Grey marlstone with marl - - - - -	9 2	
	Salt - - - - -	20 0	
	Mixed salt - - - - -	0 8	
	Salt - - - - -	3 4	
	Grey marlstone with salt - - - - -	4 0	
	Salt - - - - -	9 6	
	Brown marl - - - - -	7 4	660 0

NO. 2 BORING : ON THE AYRE AT BLUE POINT, OPPOSITE
BALLAWHANE. (See p. 282.)

(Details published by Prof. W. Boyd Dawkins in Trans. Manch. Geol. Soc., vol. xxii., p. 598, and vol. xxiii., p. 149 ; the subjoined account is from information supplied to the Survey by Messrs. Craine Bros.)

Formation.	Engineer's record.	Thickness.	Depth.
		Ft. in.	Ft. in.
[Raised Beach]	Sand and shingle - - - - -	16 0	
[Glacial]	Muddy sand - - - - -	29 0	
	Sand containing small pieces of coal - - - - -	41 0	
	Sand - - - - -	20 0	
	Clay containing small pieces of coal - - - - -	15 0	
	Silt - - - - -	50 0	171 0
[Triassic : St. Bees Sandstone]	Red sandstone - - - - -	11 6	
	do. with beds of marl - - - - -	2 3	
	do. - - - - -	20 0	
	Grey fakes [see footnote, p. 587] - - - - -	0 8	
	Red sandstone with a grey band - - - - -	14 6	
	Variegated do. - - - - -	2 0	
	Red sandstone with grey bands - - - - -	16 0	
	do. with beds of marl - - - - -	1 9	
	Reddish brown marl - - - - -	0 9	
	Reddish grey sandstone - - - - -	1 2	
	Variegated do. - - - - -	0 7	
	Red do. - - - - -	11 9	
	Brown marl with bands of sandstone - - - - -	3 3	
	Red sandstone striated with shale - - - - -	6 9	
	Red sandstone with grey bands and shaly partings - - - - -	62 9	
	Brown shale striated with red sandstone - - - - -	4 6	
	Alternations of red sandstone with thin grey bands and shale - - - - -	54 5	
	Reddish grey sandstone with traces of coal in the bedding - - - - -	1 0	
	Red and brown sandstone with thin grey bands and shale - - - - -	110 11	
	Brown fakes [see footnote, p. 587] - - - - -	30 0	
	Reddish grey sandstone - - - - -	3 3	530 9

Formation.	Engineer's record.	Thickness.
		Ft. in.
[Lower Marls]	Brown fakes - - - - -	11 3
	Red sandy shale - - - - -	24 0
	do. slightly speckled with coal	9 4
	[Fault]	
	Brown fakey limestone resembling stone-marl - - - - -	1 0
	Light grey limestone tinged with yellow - - - - -	7 2
	Blue calcareous fakes - - - - -	2 0
	Reddish limestone - - - - -	3 0
	Purple sandstone striated with soft brown limestone - - - - -	14 0
	Dark purple sandy shale striated with soft brown limestone - - - - -	10 6
[Lower Carboniferous]	Hard brown limestone with spar - - - - -	0 6
	Dark purple sandy shale - - - - -	17 8
	Conglomerate with pebble bed [see p. 284] - - - - -	3 9
	Purple sandy shale - - - - -	22 1
	Grey stone ¹ - - - - -	0 3
	Dark sandy shale - - - - -	5 9
	Dark grey calcareous stone - - - - -	2 9
	Dark shale - - - - -	6 10
	Light stone ; metal - - - - -	7 10
	do. do. with ironstone beds - - - - -	6 2
	Grey stone mixed with metal - - - - -	5 8
	Dark red dappled calcareous stone - - - - -	6 3
	Grey calcareous stone - - - - -	0 6
	Dark red stone - - - - -	1 0
	Limestone - - - - -	7 4
	Grey do. - - - - -	8 6
	Limestone - - - - -	2 6

NO. 3 BORING : ON THE RAISED BEACH AT LHEN MOOAR (p.
(Details published by Prof. W. Boyd Dawkins in Trans. Manch.
Soc., vol. xxii., p. 598.)

Formation.	Engineer's record.	Thickness.
		Ft. in.
[Raised Beach]	Sand and shingle - - - - -	12 0
	Silt - - - - -	6 0
	Grey sand - - - - -	48 0
[Glacial]	Brown sand - - - - -	26 0
	Sand and shingle - - - - -	18 0
	Shingle - - - - -	8 0
	Grey sand - - - - -	9 0
	Shingle - - - - -	40 0
	Silt - - - - -	0 6
	Carboniferous Limestone - - - - -	66 0

¹ The term "stone" from this place downwards in most cases to limestone.

NO. 4 BORING: ON THE AYRE OPPOSITE KNOCK-E-DOONEY. (p. 284.)

(Details published by J. Todd in Yn Lioar Manninagh, vol. iii., p. 72.)

Formation.	Engineer's record.	Thickness.	Depth.
		Ft. in.	Ft. in.
Raised Beach}	Sand with stones - - - -	16 0	
	Sand and gravel - - - -	20 0	
	Soft sandy clay with fragments of coal	40 0	
	Sandy clay - - - -	25 0	
[Glacial]	Sand with small pieces of coal - -	15 0	
	Sand - - - -	34 0	
	Silt - - - -	13 0	
	Gravel and clay - - - -	10 0	173 0
	Red sandstone - - - -	8 8	
	Red and grey sandstone - - - -	14 11	
	Red do. - - - -	23 3	
	Red and grey do. - - - -	7 8	
	Red do. - - - -	20 6	
	Red and grey do. - - - -	14 11	
	Red do. - - - -	22 2	
	Red and grey do. - - - -	20 6	
	Red do. - - - -	6 3	
	Red and grey do. - - - -	1 10	
	Red do. - - - -	6 9	
[Triassic : St. Bees Sandstone]	Red and grey do. - - - -	24 10	
	Red do. - - - -	13 7	
	Brown shale and red sandstone - -	1 10	
	Red and grey sandstone - - - -	3 1	
	Red do. - - - -	10 9	
	Red and grey do. - - - -	12 0	
	Red do. - - - -	13 8	
	Red and grey do. - - - -	12 4	
	Red do. - - - -	36 4	
	Red do. and shale - - - -	16 9	
	Red do. - - - -	15 5	
	Red do. and shale - - - -	26 2	
	Red do. - - - -	1 6	508 8
	Brown shale - - - -	10 0	
	Red sandstone - - - -	4 7	
	Brown shale - - - -	7 8	
	Red sandstone - - - -	12 0	
[Permian? : Lower Marls with Sandstone]	Brown shale - - - -	7 0	
	Red sandstone - - - -	9 0	
	Shale - - - -	26 0	
	Red sandstone - - - -	1 6	
	Shale - - - -	11 9	
	Sandy shale, variegated - - - -	0 6	
	Red sandstone, striated with shale -	7 0	
	do. with traces of coal - - - -	1 4	607 0
	Brown sandy shale containing small pebbles of coal - - - -	29 4	
[Permian : Brockram Series]	Coarse red sandstone - - - -	3 6	
	Dark red stone - - - -	4 0	
	do. sandstone - - - -	3 11	
	do. stone - - - -	3 0	650 9

Formation.	Engineer's record.	Thickness.
		Ft. in.
[Brockram Series, cont.]	Sandy shale - - - - -	4 9
	Dark red stone (calcareous) - -	4 4
	Conglomerate - - - - -	2 3
[Lower Carbonif- erous]	Dark red stone ; brecciated - -	2 6
	Purple sandstone with beds of brown and grey shale - - - - -	13 5
	Freestone - - - - -	12 0
	Purple sandstone - - - - -	28 3
	Purple shaly sandstone - - - -	6 0
	Variegated sandy shale with iron- stone nodules - - - - -	6 6
	Gypsum and shale - - - - -	0 6
	Variegated sandy shale with iron- stone nodules - - - - -	3 6
	Dark shale - - - - -	1 6
	Variegated sandy shale with iron- stone nodules - - - - -	4 6
	Dark purple shale with ironstone nodules - - - - -	18 11
	Dark purple shale with ironstone nodules and beds of fireclay - -	2 0
	Variegated sandy shale with iron- stone nodules - - - - -	23 9
	Dark shale - - - - -	7 0
	Shaly sandstone - - - - -	2 2
	Dark shale - - - - -	4 0
	Shaly sandstone - - - - -	7 0
	Dark shale with pyrites - - - -	4 6
	Dark shale - - - - -	5 0
	Ironstone nodule - - - - -	0 3
	Dark shale - - - - -	7 0
	Ironstone nodule - - - - -	0 3
	Dark shale - - - - -	3 0
	Ironstone nodule - - - - -	0 4
	Dark shale - - - - -	7 8
	Dark sandy shale - - - - -	1 10
	Shaly sandstone - - - - -	0 8
	Dark shale with ironstone nodules -	31 5
	Black fireclay - - - - -	0 6
	Black shale with beds and balls of ironstone - - - - -	5 9
	Dark grey shaly sandstone - - -	22 2
	Grey shaly sandstone with ironstone nodules - - - - -	14 6
	Dark shale with ironstone nodules -	20 9
	Dark shaly sandstone - - - - -	2 0
	Dark shale with iron pyrites - -	4 6
	Dark grey shaly sandstone - - -	0 6
	Dark shale with pyrites - - - -	6 3
	Shaly sandstone - - - - -	1 0
	Dark shale - - - - -	2 2
	Grey limestone - - - - -	3 0
	Dark shaly limestone - - - - -	0 10
	Dark shale - - - - -	1 6
	Grey limestone - - - - -	6 6
	Hard grey stone - - - - -	2 6

No. 5 BORING: ON THE AYRE OPPOSITE BALLAGENNEY. (See p. 286.)

(Details abridged from the borer's journal, communicated by
Messrs Craine Bros.)

Formation.	Engineer's record.	Thickness.	Depth
		Ft. in.	Ft. in
[Raised Beach]	Sand and stones- - - - -	15 0	
	Gravel - - - - -	27 0	
	Sand - - - - -	36 0	
[Glacial]	Clay - - - - -	34 0	
	Coarse sand and gravel with clay -	26 0	
	Sand - - - - -	73 8	
	Gravel - - - - -	0 8	212 4
	Red sandstone - - - - -	13 6	
	Red and grey sandstone - - - - -	0 6	
	Red sandstone - - - - -	5 9	
	Red do. with grey bands - - - - -	20 3	
	Red do. striated with shale - - - - -	1 0	
	Red do. with grey bands and shale partings - - - - -	72 6	
	Sandstone with grey bands - - - - -	142 2	
	Red sandstone with shale partings -	1 0	
	do. with grey bands - - - - -	111 11	
	Red shaly sandstone - - - - -	1 4	
	Red sandstone with grey bands - - -	127 6	
	Brown sandy shale - - - - -	0 4	
	Red sandstone - - - - -	0 6	
	Red and grey sandstone with shale partings - - - - -	1 6	
	Red and grey sandstone - - - - -	35 5	
	Sandstone plies [see p. 587] - - -	0 6	
	Red sandstone with grey bands - - -	33 6	
	Brown sandy shale - - - - -	0 5	
	Red sandstone with grey bands - - -	40 8	
	do. striated with brown shale - - - - -	4 3	
	Red sandstone with grey bands - - -	8 10	
	Brown shale - - - - -	0 3	
	Red sandstone with grey bands - - -	22 11	
	Red shaly sandstone with grey bands -	2 0	
	Red sandstone with grey bands - - -	43 3	
	Brown shale - - - - -	0 4	
	Red sandstone with grey band - - -	11 0	
	Red shaly sandstone - - - - -	8 4	
	Red sandstone - - - - -	3 0	
	do. striated with shale - - - - -	3 7	
	do. - - - - -	2 6	
	do. striated with shale - - - - -	0 6	
	Red shaly sandstone - - - - -	1 3	
	Red sandstone striated with shale -	20 0	
	do. - - - - -	1 9	
	do. and shale - - - - -	47 9	1,004 1

RECORD OF BORINGS.

Formation.	Engineer's record.	Thickness.	Depth.
		Ft. in.	Ft. in.
[Permian : Brockram Series]	Brown sandy shale with beds of grit -	14 0	1,041 1
	Conglomerate - - - -	0 6	
	Brown sandy shale - - - -	3 0	
	Brockram - - - -	19 '6	
	Purple sandstone - - - -	7 0	
	Shaly purple sandstone - - - -	2 6	
	Purple do. - - - -	6 5	
	Shaly do. do. - - - -	2 4	
	Darker do. do. - - - -	13 9	
	Variegated sandy shale - - - -	4 6	
	Dark sandstone; <i>shells</i> - - - -	7 3	
	Variegated sandstone - - - -	1 6	
	Purple and grey sandstone		
	[<i>plant-remains</i>]	9 0	
	do. shaly sandstone -	4 0	
	do. sandstone		
	[<i>plant-remains</i>]	14 9	
	do. sandstone - -	9 3	
	Sandy shale - - - -	0 4	
[Lower Carbonif- erous]	Grey sandstone and shale partings		1,30 1
	[<i>plant-remains</i>]	19 8	
	Dark shaly sandstone [<i>casts of shells</i>]	4 5	
	Grey sandy shale - - - -	3 9	
	Bluish grey shaly sandstone with brown beds - [<i>casts of shells</i>]	27 7	
	Dark sandy shale - - - -	4 6	
	Dark red shale with ironstone nodules	14 0	
	Soft shale - - - -	4 10	
	Red shale - - - -	6 9	
	Hard sandy shale - - - -	6 8	
	Limestone with beds of shale - -	4 6	
	Calcareous sandy shale - - -	3 6	
	Red sandstone - - - -	0 4	
	Shale - - - -	0 2	
	Limestone - - - -	0 9	
	Calcareous shaly sandstone - -	6 6	
	Limestone - - - -	4 2	
	Shaly limestone - - - -	2 3	
	Sandy shale - - - -	1 7	
	Red shale - - - -	0 9	
	Soft coal [<i>no core, but traces of coal in the core-tube</i>]	0 6	
	Sandy shale - - - -	0 6	
	Shaly sandstone - - - -	7 6	
	Limestone - - - -	0 8	
	Shaly sandstone - - - -	2 4	
	Limestone - - - -	2 10	
	Calcareous shale - - - -	6 0	
	Limestone - - - -	5 9	
	Shaly sandstone with gypsum - -	10 10	
	Sandy shale do. - - -	8 8	
	Shaly sandstone do. - - -	3 4	
	do. with beds of limestone	13 6	

No. 6 BORING : AT THE POINT OF AYRE. (See p. 290.)
(Details supplied by Messrs. Craine Bros.)

Formation.	Engineer's record.	Thickness.	Depth.
		Ft. in.	Ft. in.
Beach]	Shingle - - - - -	16 0	
	Gravel - - - - -	32 0	
	Sand and gravel - - - - -	8 0	
	Sand - - - - -	12 0	
	Sand and gravel - - - - -	37 0	
	Hard sand - - - - -	8 0	
	Clay - - - - -	27 0	
	Sandy clay - - - - -	8 0	
	Sand - - - - -	6 0	
	Sandy clay with stones - - - - -	10 0	
Social]	Reddish clay - - - - -	3 0	
	Sandy clay - - - - -	5 0	
	Sandy clay with stones - - - - -	10 0	
	Sandy clay - - - - -	20 0	
	do. with stones - - - - -	13 0	
	Silt - - - - -	5 0	
	Gravel with shells - - - - -	1 0	
	Sand - - - - -	7 0	
	Muddy sand with shells - - - - -	12 0	
	Reddish sand - - - - -	36 0	
	Sand and gravel - - - - -	2 0	
	do. do. with pieces of coal - - - - -	2 0	
	Gravel - - - - -	35 0	
	Coarse gravel with clay - - - - -	9 0	
	Reddish sand - - - - -	24 0	
	Gravel - - - - -	6 0	
	Stone [boulder] - - - - -	0 8	
	Gravel and sand with clay - - - - -	8 4	363 0
	Red marl with stones and gypsum - - - - -	65 0	428 0
	Brown marl with gypsum - - - - -	72 0	
	Gypsum mixed with sandy marl - - - - -	2 0	
	Brown and grey marl with gypsum - - - - -	42 0	
	Brown marl with gypsum - - - - -	3 0	
	Brown and grey marl with gypsum - - - - -	8 0	
	Grey marlstone with gypsum - - - - -	13 0	
	Brown and grey marl with gypsum - - - - -	5 0	
	Grey marlstone - - - - -	2 0	
	Brown and grey marl - - - - -	2 0	
	Grey marlstone - - - - -	8 0	
	Brown marl with veins of gypsum - - - - -	2 6	
Classic : iferous Marls]	Brown marl with salt - - - - -	0 8	
	Brown marl - - - - -	4 0	
	Grey marlstone with beds of gypsum - - - - -	2 0	
	do. with salt - - - - -	0 2	
	do. with beds of gypsum - - - - -	1 0	
	Brown marl with veins of gypsum - - - - -	2 11	
	Brown and grey marl with beds and veins of gypsum - - - - -	6 0	604 3
	Salt (1) - - - - -	12 6	
	Brown and grey marlstone with salt - - - - -	3 0	
	Salt (2) - - - - -	8 6	
	Brown and grey marlstone with salt - - - - -	6 6	
	Salt (3) - - - - -	1 6	
	Brown and grey marlstone with salt - - - - -	2 3	
	Salt (4) - - - - -	1 0	639 6

Formation.	Engineer's record.	Thickness.
		Ft. in.
	Brown and grey marlstone with salt -	6 0
	Salt (5) - - - - -	0 6
	Brown marl with salt - - - -	5 6
	Salt (6) - - - - -	4 0
	Grey marlstone with salt - - -	0 6
	Brown marl - - - - -	11 6
	Salt (7) with about 50 per cent. marl	3 8
	Brown marl - - - - -	7 0
	Salt (8) with about 25 per cent. marl	2 0
	Brown marl, with about 30 per cent. salt	1 4
	Salt (9) - - - - -	0 6
	Brown marl - - - - -	7 8
	do. with salt - - - - -	2 8
	Brown and grey marlstone - - -	6 0
	Salt (10) - - - - -	2 6
	Blue marlstone - - - - -	1 4
	do. with about 10 per cent. salt	2 10
	Salt (11) - - - - -	16 0
	Brown marl - - - - -	1 9
	Salt (12) - - - - -	1 6
	Brown and grey marl - - - - -	4 9
	Brown marl with salt - - - -	2 0
	Salt (13) - - - - -	0 6
	Brown marl - - - - -	2 0
	do. with salt - - - - -	1 6
	Blue marlstone - - - - -	3 0
	do. with salt - - - - -	0 8
	Brown and grey marlstone - - -	9 8
	Salt (14) - - - - -	1 0
	Brown and grey marlstone - - -	3 8
	Salt (15) - - - - -	0 10
	Salt with about 20 per cent. marl -	6 4
	Salt - - - - -	2 10
	Salt with about 20 per cent. marl -	4 0
	Blue marlstone - - - - -	4 3
	Brown and blue marl with salt -	9 4
	Salt (16) - - - - -	1 9
	Brown and blue marl with about	
	30 per cent. salt - - - - -	10 2
	Salt (17) - - - - -	14 0
	Brown and blue marl with salt and	
	veins of gypsum - - - - -	16 2
	Salt (18) with about 50 per cent. marl	2 10
	Brown and blue marl with veins of	
	gypsum - - - - -	4 4
	Salt (19) with about 50 per cent. marl	1 9
	Brown and blue marl with salt and	
	veins of gypsum - - - - -	2 4
	Salt (20) - - - - -	1 9
	Brown and blue marl with salt, and	
	beds and veins of gypsum - - -	16 6
	Salt (21) - - - - -	5 6
	Brown marl with salt. Breccia -	4 6
	Soft brown and blue marl with salt	
	and gypsum - - - - -	13 6
	Soft brown sandy marl with gypsum -	25 4
	Soft brown marly sandstone - - -	1 0
	Brown sandy marl - - - - -	12 4
	Soft brown marly sandstone - - -	3 4
	Soft brown and grey sandstone -	1 6
	Bluish grey sandstone - - - -	1 2

[Triassic :
Saliferous
Marls.]

JOURNAL OF A BORING IN SEARCH OF COAL NEAR PREL, MADE
ABOUT THE YEAR 1870. (See p. 279.)(Supplied by Messrs. Craine Bros., from an old record kept by the
foreman of the work.)

Formation.		Engineer's record.	Thickness.	Depth.
			Ft. in.	Ft. in.
Special]	{	Running sand - - - - -	4 0	
		Sand and gravel - - - - -	33 0	37 0
Sandstone]	{	Red sandstone with beds - - -	17 9	
		Red sandstone - - - - -	8 0	
		Red sandstone with soft beds -	24 6	87 3
		Grey fakes ¹ - - - - -	1 3	
		Fireclay - - - - -	16 3	
		Faky fireclay - - - - -	24 0	
		Grey fakes - - - - -	7 6	
		Faky fireclay - - - - -	21 1	
		Light grey fakes with grey plies ¹ -	13 0	
		Faky fireclay with spar - - -	4 0	
		Grey fakes - - - - -	3 0	
		Faky fireclay - - - - -	6 6	
		Grey fakes - - - - -	6 3	
		Fakey fireclay - - - - -	8 3	
		Grey fakes - - - - -	6 0	
		Faky fireclay - - - - -	5 3	
		Grey fakes - - - - -	5 3	
		White sandstone, extra hard - -	6 6	
		Grey fakes - - - - -	4 6	
		Green whinstone [Greenstone dyke ?]	14 0	
		do. soft - - - - -	0 6	
		Blue whinstone - - - - -	4 9	
		Soft parting - - - - -	0 3	
Intermediate Series]	{	Coarse brown sandstone, hard -	3 0	
		Faky fireclay - - - - -	4 2	
		Grey fakes - - - - -	3 4	
		Faky fireclay - - - - -	14 6	
		Dark do. - - - - -	3 6	
		Dark grey fakes and blaes ¹ - - -	1 6	
		Dark fireclay with spar - - -	3 6	
		Light faky fireclay - - - - -	13 4	
		Dark do. do. - - - - -	4 9	
		Blue fireclay and spar - - -	4 11	
		Light do. - - - - -	2 10	
		Grey sandstone, extra hard - -	3 1	
		Grey fakes and spar - - - - -	9 0	
		Grey sandstone, extra hard - -	2 2	
		Soft parting - - - - -	0 4	
		Grey kingle ¹ , extra hard - - -	8 5	
		Soft parting - - - - -	0 4	
		Grey sandstone, extra hard - -	13 1	
		Light grey fakes with white spar -	11 2	
		Dark faky fireclay - - - - -	4 11	
		Blue fireclay and spar - - -	6 4	
		Grey fakes - - - - -	6 5	
		White spar, extra hard [Quartz vein ?]	6 7	
		Dark fakes and spar - - - - -	5 0	381 6

¹Note.—BLAES = shale.
KINGLE = Hard grit.FAKES = sandy shale.
PLIES = thin parting.

APPENDIX IV.

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